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THESIS

SPECIES COMPOSITION IN BURNT AND UNBURNT DECIDUOUS DIPTEROCARP FOREST AT HUAI KHA KHAENG WILDLIFE SANCTUARY, THAILAND

THULANI SIHLE METHULA

A Thesis Submitted in Partial Fulfillment of
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The species composition in burnt and unburnt Deciduous Dipterocarp Forest (DDF) at Huai Kha Khaeng Wildlife Sanctuary (HKKWS) was carried out by identifying and comparing ground flora, seedling and sapling species. The Importance Value Index (IVI), indices for species diversity, similarity, richness and evenness were analyzed. Wildlife abundance was determined by identifying and counting dung and pellet groups of large herbivores.

Fire has an effect on the species composition of understory vegetation (ground flora, seedlings and saplings) in the DDF at HKKWS. There were more species of ground flora, seedlings and saplings in burnt area than in unburnt area. There were 55 species of ground flora found in burnt and unburnt areas. Dominant ground flora species based on the IVI value was *Heteropogon triticeus* (R.Br.) Stapf ex Craib (30.1) in burnt area and *Polyalthia debilis* (Pierre) Finet & Gagnep. (38.4) in unburnt area. Dominant seedling species was *Shorea obtusa* Wall.ex Blume (106.2) in burnt area and *Polyalthia debilis* (Pierre) Finet & Gagnep. (120.3) in unburnt area. Dominant sapling species was *Xylia xylocarpa* (Roxb.) Taub. (63.8) in burnt area and *Terminalia mucronata* Craib & Hutch. (82.3) in unburnt area.

The Menhinick's index showed that the species richness of ground flora, seedlings and saplings was higher in burnt area than in unburnt area. The species similarity of ground flora, seedlings and saplings between burnt and unburnt areas was low.

For analysing herbivore abundance the dung and pellet densities showed that elephant, banteng, Sambar deer and barking deer were more abundant in burnt area than in unburnt area and gaur did not inhabit the study area.

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Thulani Sihle Methula

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INTRODUCTION

The deciduous dipterocarp forest (DDF) is a type of seasonally dry tropical forest. Seasonally dry tropical forests occur in areas with several months of severe drought each year (Murphy and Lugo, 1986). The DDF is the most extensive forest type in Thailand, covering as much as 45% of the total forest area. This forest type occupies the dry sites in the northern, north-eastern, eastern and western parts of the country where the elevation ranges from 150 m to 1300 m above mean sea level (Bunyavejchewin, 1983; Bunyavejchewin *et al.*, 2011).

Fire is both a natural and anthropogenic disturbance influencing the distribution, structure and functioning of terrestrial ecosystems. Many plants and animals depend on fire for their continued existence (Bond, 2013). Disturbances such as wildfire can reduce plant diversity by eliminating fire sensitive species, increase species by opening up growing space and resources for use by colonising species and maintain species richness by slowing or preventing competitive exclusion in plant community composition (Peterson and Reich, 2008).

The existence of certain species in the DDF community largely depends on its regeneration under varied environmental conditions. Among the terrestrial fauna of tropical Asia, the larger species especially ungulates (elephant, gaur, banteng) and carnivores (tiger, leopard) are concentrated in the DDF and evergreen forest. The grasses and bamboo thickets of the DDF supply the main grazing during the wet season, whereas the understorey of the evergreen forest provides browse during the dry season.

Thailand's DDFs are fire dependent ecosystems (Kutintara, 1975). The insulating properties of both the sandy loam soils and the bark of savanna forest fire species make the DDF ecosystem to be well adapted to fire (Stott, 1986). As human populations have expanded their use of fire, their actions have come to dominate some ecosystems and change natural processes in ways that threaten the sustainability of some landscapes (Pausa and Keeley, 2009). Figure 1 shows the conditions of the DDF in Huai Kha Khaeng Wildlife Sanctuary (HKKWS) during different seasons.

Figure 1 The deciduous dipterocarp forest in Huai Kha Khaeng Wildlife Sanctuary; a. The DDF during the rainy season, b. The DDF during the dry season, showing the dry leaves on the ground which are fuel for wildfires in the sanctuary, c. The DDF after forest fires.

According to Bunyavejchewin (1983), wildfires occur on a yearly basis in the DDF at HKKWS which is a protected area. There have been attempts to suppress all fires especially in the protected areas. Many fire prevention programmes have been launched throughout Thailand due to environmental concerns (Wanthongchai and Goldammer, 2011).

Forage plants consumed by large herbivores consist of grasses and woody plants, which are mostly found in the understory of the DDF. These vegetation types have received little attention. The present study focused on understory vegetation species composition, herbivore abundance and soil properties, by comparing between burnt and unburnt areas at HKKWS. Therefore determining species composition of plants and the large herbivore abundance is important for proper decision making, application of management practices and understanding of how fire disturbance can affect the deciduous dipterocarp forest ecosystem structure.

OBJECTIVES

General Objective: To provide information on the current understory vegetation in order to help management of HKKWS in applying the most appropriate management practices in relation to vegetation species composition, herbivore abundance and soil properties in burnt and unburnt areas.

Specific Objectives: To determine and compare the vegetation species composition, Importance Value Index, Indices od diversity, richness, evenness and similarity of ground flora, seedlings and saplings between burnt and unburnt areas in the Deciduous Dipterocarp Forest.

To compare species abundance of large herbivores burnt and unburnt areas in the deciduous dipterocarp forest.

Concept of the Study

Forage for herbivores is influenced by many aspects of forest composition structure. Herbivores such as deer graze more heavily on grasses and forbs than on woody plants during the season. Grasses and forbs are more easily digested than woody plants during the growing season, and can represent 50-80% of herbivores diets during the growing season (McComb, 2008). Figure 2 below shows the conceptual framework of the study.

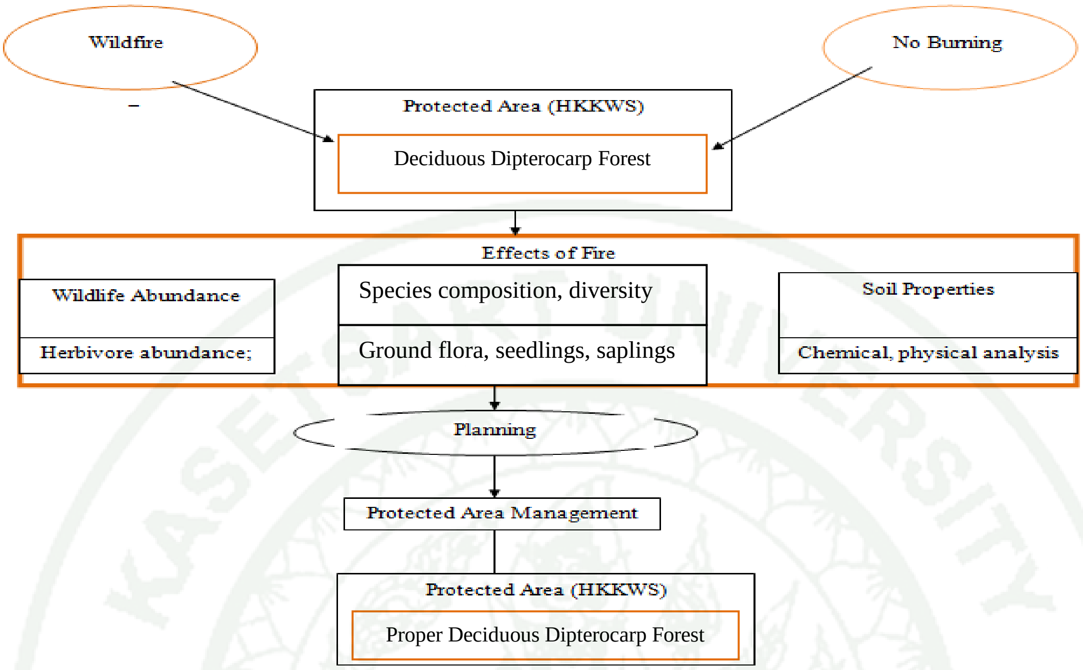

Figure 2 Conceptual Framework

Wild forest fires occur on a yearly basis at Huai Kha Khaeng Wildlife Sanctuary. Studies have shown that the fire usually starts in the DDF and spread into the mixed deciduous forest. Those are the areas with patches of grasslands, which are normally used by various wildlife.

The study focused on how wildfire affects the vegetation species composition, species diversity especially ground flora, seedlings, saplings and herbivore abundance.

LITERATURE REVIEW

1. Protected Areas

Protected areas are defined as geographical areas recognized, devoted and managed through legal means or other effective means, to attain long-term conservation of nature and its ecosystem services and cultural values (Rodriguez-Rodriguez and Martinez-Veya, 2012). Protected areas are considered to be very important for maintaining habitat integrity, species diversity (Geldmann *et al*., 2013), preserving nature and reducing biodiversity loss (Leroux *et al*., 2010).

Protected areas are useful in many ways; they secure landscapes from development and resource extraction, enhance recovery of endangered species, mitigate the effects of climate change, and protect valuable ecosystem-based services and benefits for enhancing livelihood (McCool *et al*., 2013).

According to Dudley (2008), there are six categories of protected areas.

1.1 Category I

Ia. Strict Nature Reserves are strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphic features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring. The primary objective is conserving outstanding ecosystems, species and geodiversity features with very light human impact.

Ib. Wilderness Areas are usually large unmodified or slightly modified areas, retaining their natural character and influence without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition. Their primary objective is to protect long-term ecological integrity of natural areas that are undisturbed by significant human activity.

1.2 Category II (National Parks) are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystem characteristics of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational and recreational, and visitor opportunities. Their primary objective is to protect natural biodiversity along with its underlying ecological structure and supporting environmental process and to promote education and recreation.

1.3 Category III (Natural Monuments or Feature) are areas set aside to protect a specific natural monument, which can be a landform, sea mount and submarine, geological feature such as a cave or even a living feature such as an ancient groove. Their primary objective is to protect specific outstanding natural features and their associated biodiversity and habitats.

1.4 Category IV (Habitat /Species Management Area) are areas whose priority is to protect a particular species or habitats. Most of these areas need regular, active interventions to address the requirements of particular species or to maintain habitats. Their primary objective is to conserve and restore species habitats.

1.5 Category V (Protected Landscape/Seascape) are areas where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic values. Their primary objective is to protect and sustain important landscape/seascapes and the associated nature conservation and the other values created by interactions with humans through traditional management practices.

1.6 Category VI (Protected Areas with Sustainable Use of Natural Resources)

Are areas that conserve ecosystems and habitats, together with associated cultural values and traditional natural resources management systems. Most of the area is in natural condition, where a proportion is under sustainable natural resources management. Their primary objective is to protect natural ecosystems and use natural resources sustainably, where conservation and sustainable use can be mutually beneficial.

2. Huai Kha Khaeng Wildlife Sanctuary

Wildlife Sanctuaries are areas that have been declared for conservation of wildlife habitat so that wildlife can freely breed and increase their populations in the natural environment. Wildlife sanctuaries are preserved and protected from human activity which may disturb wildlife. Tourism is discouraged in wildlife sanctuaries.

In December 1991, The United Nations Educational, Scientific and Cultural Organization (UNESCO) inscribed Huai Kha Khaeng Wildlife Sanctuary (HHKWS) under the World Heritage List (UNESCO, 2004).

Huai Kha Khaeng Wildlife Sanctuary (HKKWS) is classified under category Ia in the protected areas classification by the International Union for Conservation Nature (IUCN), mainly because of its features, roles and objectives towards conservation. It plays a major role in preserving ecosystems, species and features without or with little disturbance by humans.

Huai Kha Khaeng Wildlife Sanctuary supports a significant proportion of Thailand's animal species, including several more commonly seen in the north or south of Thailand. There are about 67 mammal species known to occur in the sanctuary. Among them are the three of the National Reserved Wildlife Species of Thailand; *Bubalus bubalis, Carpricornis summatraensis* and *Cervus porcinus*. The *Bos gaurus* and *Bos javanicus* are still fairly common, although they have become increasingly rare elsewhere due to poaching (McGinely, 2012).

Huai Kha Khaeng Wildlife Sanctuary is facing a challenge in terms of indirect human impacts. There are villages nearby the wildlife sanctuary, especially on the eastern part. These people also practice slash and burn methods as part of their agricultural practices, and during the burning process, the fire goes into the wildlife sanctuary, thus impacting on species abundance, soil physical and chemical variables and forest resources.

3. Deciduous Dipterocarp Forest

The Deciduous Dipterocarp Forest is part of the seasonally dry forests. It loses its leaves during the winter season; it is characterized by low annual rainfall and a predictable dry season. The seasonally dry forests are the most disturbed forests and least protected ecosystems on earth (Murphy and Lugo, 1986). About 42% of the world forests are dry forests (Krishnamurthy *et al.*, 2010). The DDFs are more prone to burning because the annual loss of leaves during the dry season lowers the relative humidity and increases the temperature on the forest floor, drying the fine fuels that carry low intensity fires (Bunyavejchewin *et al.,* 2011). The DDFs are well adapted to the regular occurrence of fire. The prevention of fire in the DDF leads to an increase in understory density (Wanthongchai and Goldammer, 2011).

The DDF has the fewest tree species compared to the other forest types in Thailand. It is dominated by one of 5-6 deciduous dipterocarp species (e.g. *Shorea siamensis, Dipterocarpus obtusifolius*), with the shortest main canopy of less than 25 m height, and is completely deciduous for several months during the dry season (Baker *et al.*, 2008). The groundstorey of the DDF is dominated by grasses (Williams *et al.*, 2008).

The seasonal dry tropical forests have a long history of disturbance from frequent fires and human activities. Fire is known to be an important ecological factor that helps to maintain certain types of plant communities and populations in seasonally dry regions of the world (Marod *et al*., 1999). Wildfires were first thought to rarely affect undisturbed tropical forests because of fuel characteristics and predominantly moist conditions; they are becoming an increasing common threat to tropical forests (Yeager *et al.*, 2003). In tropical forests a single wildfire can reduce woody plant composition by a third to two thirds, depending on the severity and can have negative impacts on a diverse array of faunal components (Bond and Keeley, 2005). Fire can also be used to improve wildlife habitat, to reduce the hazard of wildfire (Himmapan *et al.*, 2006). Frequent often annual, low intensity fires of human origin are common in the DDF throughout Thailand (Wantongchai *et al.*, 2008).

Forests such as the DDF, open grasslands, savannas and thorn forests are naturally pre-adapted, in differing degrees to the ecological stress of fire (Stott *et al.,* 1990). According to Bond and Keeley (2005), there are three types of forest fire; (1) crown fire, (2) surface fire and (3) ground fire. In the DDF of Thailand, surface fire usually occurs during the dry season (Buntavejchewin, 1983). Adaptations of plants in fire-prone communities, including life form and regeneration strategies promote their survival following fire (Gill, 1981). The fire adaptive strategies developed by the plants in fire-prone communities such as the DDF are; thick bark to protect the living tissue from fire damage, replacing damaged tissue quickly after fire damage, maintaining the seed bank to facilitate re-establishment after fire (VanderWeide and Hartnett, 2011).

The DDF occurs in areas with relatively severe 5-6 months dry season and a total annual rainfall of about 1,000-1,500 mm. The DDF occurs mainly in lowlands, up to 900 m above mean sea level, but extends to higher elevations in some areas where it integrates with pine forest. It grows on acidic, shallow, sand and often lateritic soils (Bunyavejchewin *et al.*, 2011).

The deciduous dipterocarp forest is a broad-leaved, deciduous forest with an open and continuous canopy composed of species with typically thick leathery leaves, with grasses in the ground layer (Aerts *et al.*, 2009; Bunyavejchewin *et al.*, 2011).

The dry deciduous dipterocarp forest is identified by four characteristic tree species; *Shorea obtusa* Wall, *Shorea siamensis* Miq, *Dipterocarpus obtusifolius* Teysum, *Dipterocarpus tuberculatus* Roxb (Bunyavejchewin, 1983).

Other important species in the canopy of DDF include *Pterocarpus macrocarpus* Kurz. *Xylia xylocarpa* Roxb. *Gluta usitata* Wall. and several species of *Terminalia*. The midstory is often characterized by species such as *Aporosa villosa* Lindl and *Strychnos nux-blanda* A.W. Hill. The understory of DDF is dominated by grasses and the dwarf bamboo. The common species are *Imperata cylindrica* L. and *Vietnamosasa pusilla* A. Cheval & A.Camus (Bunyavejchewin *et al.,* 2011).

4. Herbivores Ecology

In open woodlands such as the DDF, a dominant ground cover of grasses and forbs is exploited by herbivores. The herbivores have evolved to exploit the grasses and forbs that result from an open canopy and frequent fire regimes. Ungulates can influence the fire regime by altering the amount of flammable material on the forest floor and shifting plant composition (McShea and Baker, 2011).

4.1 Common barking deer *Muntiacus muntjak* Zimmermann

The common barking deer is a small ungulate that is native to Asia and has wide distribution range, with a high breeding potential (Sukmasuang, 2001). The common barking deer occurs in all forest types. It is more of a browser than a grazer. The common barking deer are solitary almost all year round. They form pairs during the rutting season, between December and January when the antlers are well hardened (Lakagul and McNeely, 1988). Most of its range is dominated by evergreen vegetation, but it readily uses the deciduous forests and mosaics of grasslands, scrub and forest. The diet of the barking deer mainly consists of fruits, buds, tender leaves, flowers, herbs, and young grass (Black and Gonzalez, 2008).

4.2 Sambar deer *Cervus unicolor* Kerr

This species is well adapted to a variety of forest types and environmental conditions (Lakagul and McNeely, 1988; Black and Gonzalez, 2008), it prefers wooded areas, including dense jungle (Lakagul and McNeely, 2008). It browses or grazes depending on the forage available at the time (Black and Gonzalez, 2008); they are more of browsers than grazers (Lakagul and McNeely, 1988). In protected forest areas of Thailand, the Sambar deer populations are often concentrated around athropogenic grass and scrub, rather than the forest itself (Black and Gonzalez, 2008).

4.3 Banteng *Bos javanicus* D'Alton

Bos javanicus are found throughout the mainland of Southeast Asia, including Thailand. The banteng prefer more open areas, especially the plains or the Deciduous Forest (Lakagul and McNeely, 1988); they avoid the evergreen rainforest (Burton and Hedges, 2008). Banteng prefer grazing to browsing (Lakagul and McNeely, 1988; Burton and Hedges, 2008), but they also consume a lot of browse and fruits depending on the season and local food availability (Burton and Hedges, 2008).

It was directly observed that banteng consume 143 plant species in the wet season and 82 species in the dry season at HKKWS. Bantengs' range is restricted to the DDF because of their preference for grasses and forbs which are abundant in the open canopy forests such as the DDF (Bhumpakphan and McShea, 2011).

4.4 Gaur *Bos gaurus* Smith

The gaur inhabits forests of all elevations (Lakagul and McNeely, 1988), but prefers elevations from sea level up to at least 2800 m above sea level (Wood, 1937; Wharton, 1968; Burton and Hedges, 2008). The evergreen forest, semi-evergreen forest, and moist deciduous forest are the most preferred forest types by the gaur. They also occur in the dry deciduous forests (Burton and Hedges, 2008). In Huai Kha Khaeng Wildlife Sanctuary, gaur use the DDF less during the dry season, except immediately following fires when there is an increase of new grasses (Bhumpakphan and McShea, 2011).

The gaur are grazers and browsers, they eat mostly young green grasses, leaves, fruit, twigs, and barks of various woody species, as well as coarse dry grasses and bamboo (Burton and Hedges, 2008). They prefer browsing on edible leaves near watering points (Lakagul and McNeely, 1988). In HKKWS, Gaur feed on leaves of twigs of *Bauhinia*, *Diospyros ehretioides*, *Hymenodictyon eroxense*, *Anogeissus acuminata*, *Butea superba*, and *Saccharum spontaneum*; the leaves and shoots of *Bambusa nutans*, *Dendrocalamus strictus, Gigantochloa albociliata*, and *Thyrsostachys siamensis*; and fruits of *Dillenia parvifolia* and *Dillenia indica* (Bhumpakphan and McShea, 2011).

4.5 Asian elephant *Elephas maximus* Linnaeus

Asian elephants are also called a keystone species (Fernando and Leimgruber, 2011), they are generalists and they occur in grasslands, tropical evergreen forest, semi-evergreen forest, moist deciduous forest, dry deciduous forest, and dry thorn forest (Hedges and Desai, 2008). They browse and graze on a variety of plants. Their diet varies according to season and habitat. During the dry season, 70% of their diet is browse, during the wet season, up to 55% of their diet is grass. According to Sukmasuang (1993), in the dry season, the Asian elephants prefer to use the dry evergreen forest and the mixed deciduous forest during the wet season.

Elephant density might be one of the most crucial factors determining their ecological role (Holdo *et al*., 2009). Increased densities of browsing elephants can be detrimental to woodland ecosystems by suppressing and reducing the diversity of plant species and other biodiversity components. The highest Asian population densities occur along forest-grasslands or forest-agriculture ecotones where food plants become more abundant and accessible (Fernando and Leimgruber, 2011). Generally population densities of Asian elephants are believed to be higher in seasonally dry forests compared to other forest types (Fernando and Leimgruber, 2011). The seasonally dry forests provide abundant and diverse foods consisting of grasses, woody plants and their component parts (Sukumar, 2003). Asian elephants prefer feeding on grass; they switch to browse when grasses are unavailable (Sukumar, 2003).

In the seasonal dry forests such as the DDF, grasses and shrubs in the understory are more common and more easily accessible than in other forest types. Elephants are well adapted to open canopy forests mainly due to their feeding habits of switching between grazing and browsing (Fernando and Leimgruber, 2011).

5. Effects of Wildfire

Wildfire can have positive, negative or both positive and negative effects on vegetation, soil and wildlife. Wildfire effects on dry tropical forests include acceleration of nutrient cycling, mortality of individual trees, shifts in successional direction, induced seed germination, loss of soil seed bank, increased landscape heterogeneity, alteration of surface-soil organic layers, changes in underground plant-root and reproductive tissues, and volatilization of soil nutrients (Dale, 2011).

Wildfire has resulted in the disturbance and changes in numerous ecosystems. Forest fires have caused reductions in forest area, retarded tree growth rate and reduced wood quality. Vegetation has been killed by high temperature and wild animals may become extinct. Soil nutrients could be depleted (Himmapan *et al.*, 2006). The ecological impact of fire varies from vegetation formation to formation even within the same habitat, different management practices are required to achieve different ecological and productive goals (Stott *et al.*, 1990).

According to Bond and Keeley (2005), the three types of forest fire are; (1) crown fire, burns the canopy of shrubs and trees, (2) surface fire, spreads by fuels that are close to the ground, such as grass or deed leaf and stem material and (3) ground fire, burns soils that are rich in organic matter.

In the seasonally dry forests such as the DDF, fire has been used to clear vegetation, or to maintain a forest structure to produce a specific range of non-timber forest products that are favoured by fire (Wanthongchai and Goldammer, 2011). According to Dale (2011), tree species in seasonally dry forests are well adapted to fire and they exhibit many fire-resistant characteristics, such as thick barks, ability to heal fire scars, a high capacity to resprout through coppicing or by means of epicmic shoots from dormant buds and lignotubers and special seed characteristics. The dominant tree species in the fire-prone ecosystems have developed mechanisms for tolerating periodic fires (VanderWeide and Hartnett, 2011).

A policy of fire exclusion in Thailand leads to groundcover associations that give rise to extreme groundcover burns which are said to be a dangerous type of fire. The primary vegetation of Thailand is open deciduous forests and savanna, fire is a regular feature of this vegetation lass. If fire was excluded from the landscape, fuels would be expected to build up thus resulting in high intensity fires which will be difficult to suppress and may sometimes progress to the evergreen forest (Stott, 1986).

5.1 Effect of Wildfire on Vegetation Species Composition

Species composition is the number of species in a community. Species evenness refers to how the species abundance is distributed among species in a community. Species composition and evenness results in species diversity. Species diversity is made up of these two components. Communities dominated by one or a few species have a low evenness, while those that have a more even distribution of species have a high evenness (Sultana, 2006). Common anthropogenic activities including burning have a tremendous impact on the regeneration of tree species (Prasad and Al-Sagheer, 2012).

Wildfire plays a big role in the evolution of most of the world's grasslands and forests. Lightning, human negligence, malice, volcanic activity, spontaneous combustion is the primary causes of fires (Holecheck *et al.*, 2004; Subberndieck *et al.*, 2007). Wildfire in natural communities has often been observed to create opportunities for seed germination and seedling establishment. Fire may allow new species to enter the burned community (Glascow and Matlack, 2007).

Burning of vegetation often results in earlier grass growth at the beginning of the growing season and greater annual dry matter production (Blair, 1997). This is attributed to the removal of the dead surface litter which results in greater light penetration and higher soil temperatures in spring (Fynn *et al.*, 2003).

Reduced productivity and nutrients pools may be depleted by frequent burning; infrequent burning or fire exclusion increases the risk of high-intensity wildfire and promotes the gradual replacement of the DDF ecosystem by a more aggressive, less fire-tolerant, and often less desirable ecosystem (Wanthongchai *et al.,* 2008). The accumulation of dead standing litter produces highly flammable fuels at a rate surpassing any flammable wood vegetation (Bond and Parr, 2010).

Wildfire helps to maintain the stability of grasslands by reducing the establishment of trees and shrubs, releasing nutrients bound up in organic matter, and accelerating the rate of decomposition in the soil (Ford and Johnson, 2006). The existence of certain species in the DDF community largely depends on its regeneration under varied environmental conditions. Regeneration is a critical phase of forest management; it maintains the desired species composition and stocking after disturbance (Prasad and Al-Sagheer, 2012). Grasses and forbs are typically found in abundance beneath or between overstory tress in open stands or following a large disturbance such as fire (McComb, 2008).

5.2 Effect of Wildfire on Soil Properties

Soil plays a major role in the structure of forests and wildlife abundance. It provides a growth medium for plants and contributes to biodiversity. The soil is a reservoir for plant nutrients and water. Plants get most of their life requirements from the soil. When soil is exposed to fire, its nutrient composition and water holding capacity is bound to change. The effect of the changes is dependent on the soil type, fire severity, the plant and animal species, the reaction of the various nutrients and the water holding capacity.

The species composition of plants is influenced by the soil, climate and management. The composition varies between areas, and from year to year, as it is considerably affected by rainfall, fire and grazing (Holecheck, et al., 1999).

Wildfire can produce physical, chemical and biological alterations in soil properties and are one of the major causes of soil degradation (Mataix-Soleira *et al.,* 2011; Grangled *et al.,* 2011). The effects of wildfires on soil chemical properties include complex biogeochemical interactions between soil components. Soil pH may be the variable most reported by authors working on fire-affected soils. Changes in soil pH immediately after burning can affect solubilisation/insolubilisation dynamics of soil nutrients (Grangled *et al.,* 2011).

Occurrence of wildfires in forest ecosystems has lasting effects on both the microbial composition and the organic matter, and hence on the whole soil dynamics. The alteration of natural ecosystems affects organic matter turnover and therefore productivity and community structure may be also affected (Gonza´lez-Pe´reza *et al.,* 2004).

Severe fires can result in the following effects: 1) loss of organic matter and nutrients through volatilization, ash entrapment in smoke columns, leaching and erosion; 2) alterations both quantitative and qualitative of microbial communities; and 3) deterioration of soil structure by affecting aggregate stability (Mataix-Solera *et al*., 2011). Wildfire can also increase runoff which can lead to floods and erosion (Stoof *et al.,* 2010).

Soil chemical properties are important in regard to plant growth. Many properties such as soil reaction (pH), organic matter, total nitrogen, potassium, phosphorus, etc. are recognized as essential for plant development (Sultana, 2006).

Soil pH is a factor that defines the fertility status of a soil, whose level determines the availability of most essential plant nutrient elements as well as influencing plant growth. Most plants grow well within the soil water pH between 5.5 and 6.5 (Jones, 2012).

Organic matter is important for improving physical properties, increasing water holding capacity, soil nutrients and reducing susceptibility to erosion (Sultana, 2006; Jones, 2012). Plant litter and plant root input into broadleaved forest soils are the main sources of organic matter (Antisari *et al.,* 2010). Soil organic matter input from above and below the ground can significantly affect the nutrient pools and storage in soils (Neary *et al.,* 1999).

Nitrogen (N) regulates net plant primary production in most ecosystems (Jones *et al.,* 2004). Nitrogen utilization enhances plant growth through the formation of amino acids, proteins, nucleic acids and other cellular constituents (Alvarado *et al.,* 2000).

Phosphorus (P) is a vital component of macromolecules such as nucleic acids, phospholipids, sugar phosphate (Ma *et al.,* 2009). It is required for diverse homeostatic and signal transduction cascades. Plant roots acquire phosphorus from the soil solution as phosphate (Amtmann *et al.*, 2006).

Potassium (K) plays an important role in metabolism, and is required for charge balancing and transport of metabolites (Amtmann *et al.,* 2006).

5.3 Effect of Wildfire on Wildlife Abundance

Wildlife abundance and dispersal is related to the habitat requirements and welfare factors. Changes in habitat may have an effect on change of species and population (Bhumpakphan, 2003).

Wildlife populations can be affected directly or indirectly by wildfire (Monroe and Converse, 2006). Wildlife response to fire can be influenced by factors such as timing of reproduction, duration of breeding period, vagility, and resistance to desiccation characteristics (Pilloid *et al.,* 2003). These factors and species characteristics can determine if a species reacts in a positive or negative towards the fire effects.

The direct effects could be wildlife mortality; the amount of direct mortality may depend on the intensity of the fire as well as the physiological status of the wildlife at the time of the time of the fire (Monroe and Converse, 2006).

Indirect effects are by altering habitat characteristics and resource availability. The indirect effects influence population abundance and persistence (Haslem *et al.,* 2012). Wildlife population estimates are often based on direct or indirect (often referred to as population indices) methods (Alves *et al*., 2013).

Population indices only give an estimate of the overall population abundance (Acevedo *et al*., 2010). The population abundance estimates are obtained by monitoring and counting a given sign, e.g., faecal pellets or dung that has to be positively and linearly correlated with the abundance of a species (Alves *et al*., 2013).

If fire is used appropriately, it can create a suitable habitat for wildlife such as deer and hare which feed on the understory vegetation that is stimulated by fire.

6. Species Diversity

Species diversity is a product of richness and evenness. Species diversity is made up two components the first is species richness which is the number of species in a community. The second component is species evenness, it refers to how the species abundance is distributed among species in a community (Sultana, 2006).

7. Protected Area Management

Protected areas are very important in biodiversity conservation, and in the implementation multilateral environmental agreements (Stoll-Kleeman, 2010). The management of protected areas includes the structures, processes, and determines how stakeholders contribute (Lockwood, 2010).

In some developing countries, attempts apply management models are affected negatively, mainly due to interference from local communities including unsustainable resource extraction, poaching, and sabotage (Lockwood, 2010).

In most cases, protected areas depend on the surrounding landscapes for their organism flow maintenance, water, nutrients and energy. Protected areas managers have little authority over surrounding landscape, although land use change and infrastructure development can have major impacts on the integrity of a protected area (DeFries, *et al*. 2010).

Small, expected and frequent disturbances such as the annual forest fires at Huai Kha Khaeng Wildlife Sanctuary are easier to study, understand, and plan for. For management purposes, the conditions that lead to or result from the disturbances need to be understood so that the alternatives for manipulation can be developed when possible (Dale, 2011).

The complexity and controversial issues related to the role of fire in the DDF is a challenge for the development of principles of fire management (Wanthongchai and Goldammer, 2011). The DDF is a fire-dependent ecosystem, and it should be properly managed as a priority conservation goal for bovid as well as many other animals and plants. The DDF and open grassland habitat should be manipulated for gaur, banteng and other ungulates through prescribed burning in the early dry season (Bhumpakphan and McShea, 2011).

MATERIALS AND METHODS

Study Site

The study was conducted in the Uthai Thani Province at Huai Kha Khaeng Wildlife Sanctuary. The HKKWS was declared a National World Heritage Site by UNESCO in December 1991. It is located in the western part of Thailand (15^0 00’ to 15^0 50’ N, 99^0 00’to 99^0 28’E) and 2,750 km² in size. The main area lies in Lan Sak, Huai Khrot and Ban Rai districts in Uthai Thani Province, a small part of the area at the north is located in Umphand district, Tak Province. The northern boundary is with Nakron Sawan and Tak Province and the southern borders are with Khanchanaburi and Suphanburi Provinces (Himmapan and Kaitpraneet, 2008).

The elevation ranges between 300 m and 1,700 m above mean sea level. The climate is tropical, seasonal (Johnson, 2003). There are three distinct seasons; summer is from February to April, with temperatures ranging from 24-38^0 C, rain season from May to October, with temperatures ranging from 23-34^0 C, winter is from November to January, with temperatures ranging from 18-20^0 C. The annual rainfall is 1,500 mm (Wiriya, 2009).

The main vegetation covers in the Huai Kha Khaeng Wildlife Sanctuary are the deciduous dipterocarp forest, mixed deciduous forest, evergreen forest and bamboo forest. In lowland areas, mainly near the large rivers, there are small portions of open grasslands.

The study was carried out in the deciduous dipterocarp forest, which is 12.35% of the total forest cover in the wildlife sanctuary. Two sites were selected, one which has been subjected to fire on an annual basis (burnt area) and one which has not been subjected to fire for the past 5 years (unburnt area). The map of the study site is shown in figure 3 below.

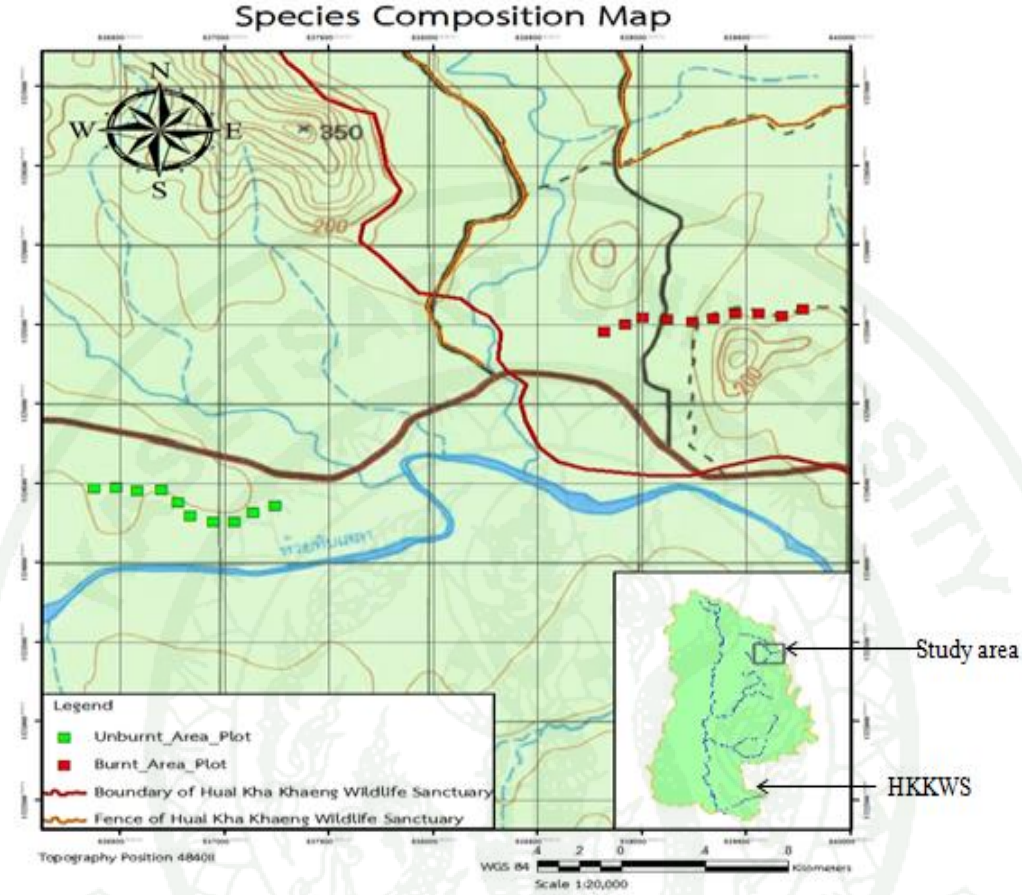

Figure 3 Map of HKKWS also showing study area

Materials

1. Secondary data
2. Measuring tape
3. Vernier caliper
4. String
5. Data sheet
6. Plastic and paper bags
7. Scissors
8. Camera
9. Computer
10. GPS and compass
11. Weight scale
12. Statistical software
13. Stereo microscope

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Methods

1. Vegetation Sampling

The vegetation sampling was carried out at the end of the growing season (February, 2014); this was to facilitate the easy identification of flowering plants. The data was collected from two sites of the deciduous dipterocarp forest, unburnt and burnt site. In each site the area was divided according to the vegetation homogeneity, and then demarcated according to their landscapes. A line transect of 1,100 m was set, at every 100 m plots of 10 m x 10 m. At the four corners, sub-plots of 0.5 m x 0.5 m were set for ground flora sampling. Plots of 1 m x 1 m and 4 x 4 m were set on one corner for seedling and sapling sampling respectively. Smitinand (2001) was used for plant identification in the study.

Ground Flora Sampling: In this study the ground flora is defined as all vegetation life forms less than 130 cm height; shrubs, climbers and herbaceous plants. Shrubs are woody perennial plants of lower stature and sometimes several basal stems. Herbs are flowering plants with no woody tissue above the ground, they include grasses and forbs. Forbs are non-grass-like plants with tap root, generally broad leafed with solid non-jointed stems. For determining species composition of ground flora in burnt and unburnt areas, the species within the plots were recorded. Template specimens were collected and later compared and identified at the Forest herbarium, Department of National Parks, Wildlife and Plant Conservation as shown in figure 4 below.

Figure 4 Template specimen of ground flora species (a), herbarium specimen (b), *Imperata cylindrica* (L.) P.Beauv.

The data for the ground flora was collected from the 0.5 m x 0.5 m plots. There were 40 plots in each site. For determining the biomass which was later used for calculating the dominance, the ground flora within the plots was cut at ground level, sorted according to species, weighed and oven dried at 72º C for 48 hours. After oven drying the samples were weighed again in order to calculate the biomass.

In order to determine the quantitative relationships between the ground flora species in a burnt area and an unburnt area, the importance value index was determined (Saravanan *et al*., 2014). The importance value index for ground flora was calculated using the following equation (Whittaker, 1970):

$$IVI= RF+RDo \quad (1)$$

Where,

IVI= Importance Value Index

RF= Relative frequency

RDo= Relative dominance

$$\text{Frequency (F)} = \frac{\text{Number of plots in which a species occurs}}{\text{Total number of sample plots (40)}}$$

$$\text{Relative frequency (RF)} = \frac{\text{Frequency value for a species (F)}}{\text{Total of all frequency values for all species}} \times 100$$

$$\text{Dominance (Do)} = \frac{\text{Biomass of a species}}{\text{Area sampled } (0.25\text{m}^2)}$$

$$\text{Relative dominance (RDo)} = \frac{\text{Dominance of a species (Do)}}{\text{Total dominance for all species}} \times 100$$

Seedlings' sampling: In the study, seedlings were defined as small woody plants with a height less than 130 cm. For determining species composition of the seedlings in both burnt area and unburnt area, they were identified and recorded. The diameter of seedlings was measured at the base of the plant.

Template specimens were collected and later compared and identified at the Forest herbarium, Department of National Parks Wildlife and Plant Conservation.

In order to determine the quantitative relationships between the seedlings' species in a burnt area and an unburnt area, the importance value index was determined (Saravanan *et al*., 2014). The importance value index for seedlings was calculated using the following equation (Whittaker, 1970):

$$IVI = RD + RF + RDo \quad (2)$$

Where,

IVI= Importance Value Index
RD= Relative density
RF= Relative frequency
RDo= Relative dominance

$$\text{Density (D)} = \frac{\text{Total number of plants}}{\text{Total area of sampled plots } (1m^2)}$$

$$\text{Relative density} = \frac{\text{Density of a species}}{\text{Total density of all plants}} \times 100$$

$$\text{Frequency (F)} = \frac{\text{Number of plots in which a species occurs}}{\text{Total number of sample plots (10)}}$$

$$\text{Relative frequency (RF)} = \frac{\text{Frequency value for a species (F)}}{\text{Total of all frequency values for all species}} \times 100$$

$$\text{Dominance (Do)} = \frac{\text{Total basal area of a species}}{\text{Area sampled } (1\ m^2)}$$

$$\text{Relative dominance (RDo)} = \frac{\text{Dominance of a species (Do)}}{\text{Total dominance for all species}} \times 100$$

Sapling Sampling: Saplings were defined as trees and shrubby trees of more than 130 cm height and diameter at breast height (DBH) less than 4.5 cm. For determining species composition of the saplings in both burnt area and unburnt areas, they were identified and recorded. Template specimens were collected and later compared and identified at the Forest Herbarium, Department of National Parks Wildlife and Plant Conservation.

In order to determine the quantitative relationships between the seedlings' species in a burnt area and an unburnt area, the importance value index was determined (Saravanan *et al*., 2014). The importance value index for saplings was calculated using the following equation (Whittaker, 1970):

$$IVI = RD + RF + RDo \tag{3}$$

Where,

IVI= Importance Value Index
RD= Relative density
RF= Relative frequency
RDo= Relative dominance

$$\text{Density (D)} = \frac{\text{Total number of plants}}{\text{Total area of sampled plots (16 m}^2\text{)}}$$

$$\text{Relative density (RD)} = \frac{\text{Density of a species}}{\text{Total density of all plants}} \times 100$$

$$\text{Frequency (F)} = \frac{\text{Number of plots in which a species occurs}}{\text{Total number of sample plots (10)}}$$

$$\text{Relative frequency (RF)} = \frac{\text{Frequency value for a species (F)}}{\text{Total of all frequency values for all species}} \times 100$$

$$\text{Dominance (Do)} = \frac{\text{Total basal area of a species}}{\text{Area sampled (16 m}^2\text{)}}$$

$$\text{Relative dominance (RDo)} = \frac{\text{Dominance of a species (Do)}}{\text{Total dominance for all species}} \times 100$$

The sampling plots designed for the vegetation data collection are shown in figure 5 below.

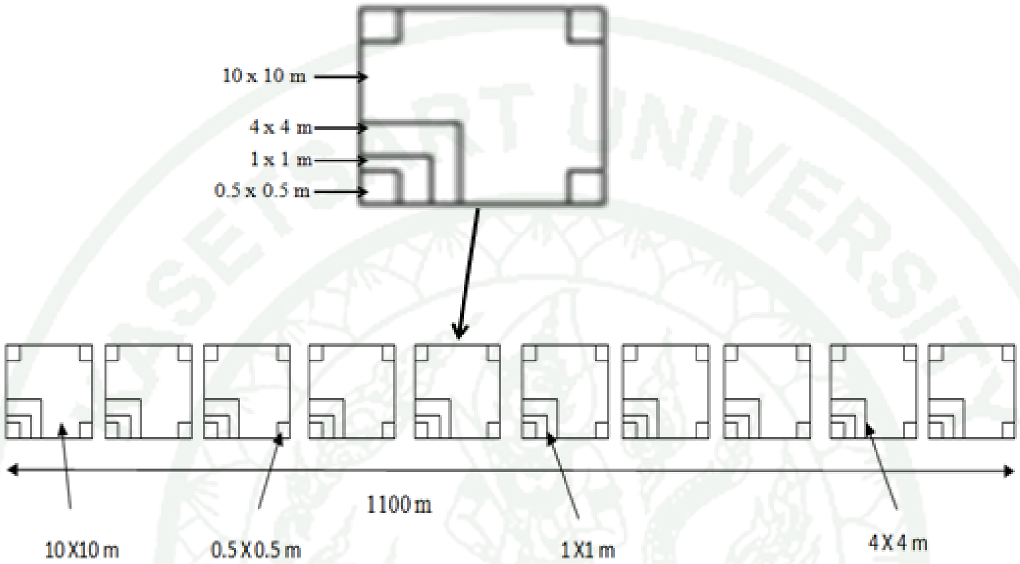

Figure 5 Experimental design for vegetation sampling

Tree Sampling: Trees were defined as woody perennial plants more than 130 cm height and diameter at breast height (DBH) equal to or more than 4.5 cm. The trees were sampled in one 50 m x 10 m plot in burnt area and unburnt area. In order to determine the forest structure, a 50 m x 10 m plot was set along the transects in both burnt and unburnt areas. Trees with a diameter of ≥4.5 cm at breast height (130 cm) were identified and recorded. Their height and canopy cover was also recorded. The percentage cover of the canopy, mid layer and lower layer was determined. The canopy percent cover was determined from trees of 15 m-25 m height, the mid layer percent cover was determined from trees of 6 m-15 m height and lower layer percentage cover from trees of up to 5 m height.

The following equation was used to calculate the percent canopy cover without accounting for overlaps (Crookston and Stage, 1999).

Where,

$$C = 100\ (\Sigma p_i a_i)\ A^{-1} \qquad (4)$$

C= % canopy cover without accounting for overlap

P_i= trees per hectare fot the i th sample tree

a_i= projected crown area for the i th in m^2/ha

A= m^2/ha

For determining the species composition and IVI of the trees, the 50 m x 10 m plots were sub divided into 10 m x 10 m plots. In order to determine the quantitative relationships between the trees in a burnt area and an unburnt area, the importance value index was determined (Saravanan *et al*., 2014). The importance value index for trees was calculated using the following equation (Whittaker, 1970):

$$IVI = RD + RF + RDo \qquad (5)$$

Where,

IVI= Importance Value Index
RD= Relative density
RF= Relative frequency
RDo= Relative dominance

$$\text{Density (D)} = \frac{\text{Total number of plants}}{\text{Total area of sampled plots (500 m}^2\text{)}}$$

$$\text{Relative density (RD)} = \frac{\text{Density of a species}}{\text{Total density of all plants}} \times 100$$

$$\text{Frequency (F)} = \frac{\text{Number of plots in which a species occurs}}{\text{Total number of sample plots (5)}}$$

$$\text{Relative frequency (RF)} = \frac{\text{Frequency value for a species (F)}}{\text{Total of all frequency values for all species}} \times 100$$

Total basal area of a species

$$\text{Dominance (Do)} = \frac{\qquad\qquad}{\text{Area sampled (500 m}^2\text{)}}$$

$$\text{Relative dominance (RDo)} = \frac{\text{Dominance of a species (Do)}}{\text{Total dominance for all species}} \times 100$$

Species Diversity: In order to determine the species diversity of ground flora, seedlings, saplings and trees in a burnt area and an unburnt area, the Shannon-Weiner Index of diversity was used.

The Shannon Wiener Index (H)

According to Shannon (1948), this index is based on communication theory and stems from a common question in communication. The Shannon Wiener Diversity Index will be used to determine species diversity for the vegetation samples.

$$H= -\Sigma\ [pi \ln pi] \qquad (6)$$

Where,

H= Shannon-Wiener Diversity index

pi= Proportion of total sample made up of the i th species.

Species Evenness: It is the relative abundance which each species is represented in an area (Shannon, 1948).

$$E= \frac{H}{\ln (S)} \qquad (7)$$

Where,

E= Evenness

H= Shannon Wiener diversity index

S= Number of species

Species Richness: To determine and compare the species richness between burnt and unburnt areas the Menhinick's index was used. The Menhinick's index is calculated using the following equation (Whittaker, 1977).

$$D= \frac{S}{\sqrt{N}} \tag{8}$$

Where,

D= Species richness

S= Number of different species represented in sample

N= Total number of individual organisms in sample

Species Similarity: To determine the level of similarity between ground flora, seedlings, saplings and trees in burnt and unburnt areas, the Sorensen Index was used.

Sorensen Index

This is the simplest method for evaluating the similarity between two quadrant samples. The value will be close to 1 if the sites have most of their species in common and for very dissimilar sites, the value would be close to 0. The species similarity was calculated using the following equation (Sorenson, 1948).

$$QS= \frac{2C}{A + B} \tag{9}$$

Where,

QS= is the quotient of similarity and ranges from 0-1.

C= number of species occurring in both burnt and unburnt areass

A= number of species in burnt area.

B= number of species in unburnt area.

2. Soil Sampling

Three soil samples were collected from each site (0 m, 550 m, 1100 m) at two depth levels (0-25 cm and 25-50 cm) as shown on figure 6.

Figure 6 Soil sampling

The soil samples were taken at 3 different points along each transect of 1100 m to capture variation and at two depths to ensure that plant nutrients available to both short rooted plants and deep rooted plants are determined. At each sampling point, soil samples were first taken from the topsoil (0-25 cm), and the topsoil was then removed with a hoe, taking care not to unnecessarily disturb the soil when taking the subsoil (25 cm- 50 cm) sample (Agyare, 2004). The soil samples were then put in polythin bags then sent to the Soil Science Laboratory, Faculty of Forestry, Kasetsart University for analysis. The following soil elements were analysed; pH, organic matter, total nitrogen, available phosphorus, exchangeable potassium, exchangeable calcium, ash and moisture content.

3. Wildlife Abundance Sampling

Wildlife indices in the form of dung and pellet density were used to determine the large herbivores abundance in the burnt and unburnt site. The Faecal Standing Crop (FSC) method was used. The herbivore abundance in burnt and unburnt areas was then be determined, compared and tested by statistics.

The herbivores abundance was determined by monitoring and counting the dung and pellets of wild herbivores such as the elephant, gaur, banteng, Sambar deer and the common barking deer (Bhumpakphan, 2003).

A line transect of 1100m was used (Same transacts and plots as the ones for vegetation sampling). Every 100 m, plots of 10mX10m were set and the dung count for large herbivores such as Asian elephants, gaur and banteng was conducted. Smaller plots of 1m X 1m were set at the corners of the larger plots, faecal pellet groups of common barking deer and Sambar deer were identified and counted. For Sambar deer and common barking deer, the plots were smaller in order to improve pellet detection. The dung density and pellet group density was then calculated. Only 5 species (Asian elephants, Banteng, Gaur, Sambar deer and common barking deer) of herbivores were considered in the study. Figure 7 shows the plot design for dung and pellet sampling.

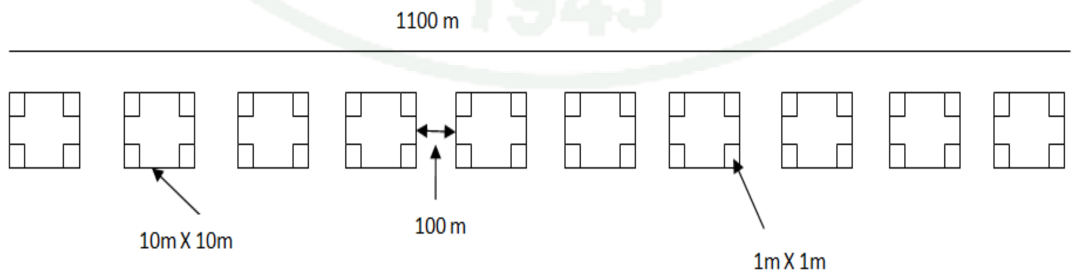

Figure 7 Experimental design for wildlife abundance sampling

The dung and pellets were calculated by a formula for density (Bhumpakphan, 2003).

$$\text{Dung or Pellet Density} = \frac{\text{Number of dung or pellets}}{\text{Total Area}} \times 100 \qquad (10)$$

4. Statistical Analysis

All data was entered into Microsoft Excel and data processing and analysing was done. To get the comparative account of vegetation species composition and wildlife abundance from an unburnt area and a burnt area the two-sample t-test of SPSS were used for determining the level of significant difference.

RESULTS AND DISCUSSION

Results

1. Vegetation Species Composition

Species composition of ground flora

From all the 80 ground flora plots there were 55 species found from 28 different families. The total number of species found in burnt area was 35 species from 19 different families. The total number of species found in unburnt area was 33 species from 20 different families as shown in table 1.

Table 1 Species composition of ground flora

No.	Family	Botanical Name	B	UB
1	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	–	x
2	Annonaceae	*Uvaria argentea* Blume	x	–
3	Apocynaceae	*Holarrhena curtisii* King & Gamble	x	–
4	Barringtoniceae	*Careya sphaerica* Roxb.	–	x
5	Bignoniaceae	*Fernandoa adenophylla* (Wall. ex G.Don) Steenis	x	–
6	Bignoniaceae	*Markhamia stipulata* Seem.	–	x
7	Combretaceae	*Terminalia mucronata* Craib & Hutch.	x	–
8	Commelinaceae	*Commelina diffusa* Burm.f	x	x
9	Commelinaceae	*Murdannia spirata* (L.) G. Bruckn.	–	x
10	Compositae	*Chromolaena odorata* (L.) R.M. King & H. Rob.	x	x
11	Compositae	*Elephantopus scaber* L.	–	x
12	Compositae	*Praxelis clematidea* R.M. King& H. Rob.	x	x
13	Compositae	*Spilanthes iabadiensis* A.H. Moore	–	x
14	Costaceae	*Costus speciosus* (Koen ex. Retz.) Sm.	x	–
15	Cyperaceae	*Cyperus cyperoides* (L.) Kuntze	x	x
16	Cyperaceae	*Cyperus haspan* L.	–	x
17	Cyperaceae	*Diplacrum caricinum* R. Br.	x	x
18	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	x	–
19	Erythroxylaceae	*Erythroxylum cambodianum* Pierre	–	x
20	Euphorbiaceae	*Croton hutchinsonianus* Hosseus	x	x

Table 1 (Continued)

No.	Family	Botanical Name	B	UB
21	Flacourtiaceae	*Casearia grewifolia* Vent.	–	x
22	Gramineae	*Cyrtococcum patens* (L.) A. Camus	x	x
23	Gramineae	*Eragrostis atrovirens* (Desf.) Steud.	–	x
24	Gramineae	*Heteropogon triticeus* (R.Br.) Stapf ex Craib	x	x
25	Gramineae	*Imperata cylindrica* (L.) P.Beauv.	x	–
26	Gramineae	*Oplismenus compositus* (L.) P. Beauv.	–	x
27	Gramineae	*Panicum maximum* Jacq.	–	x
28	Gramineae	*Pennisetum polystachion* L. Schult.	x	–
29	Gramineae	*Sacciolepis turgida* Ridl.	x	–
30	Gramineae	*Setaria parviflora* (Poir.) Kerguelen	x	–
31	Gramineae	*Themeda triandra* Forssk. G	x	–
32	Gramineae	*Vetiveria nemoralis* A. Camus	x	x
33	Labiatae	*Pogostemon quadrifolius* Kuntze.	x	–
34	Lauraceae	*Beilschmiedia fagifolia* Nees	–	x
35	Lauraceae	*Litsea glutinosa* (Lour.) C.B. Rob.	–	x
36	Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.	–	x
37	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	x	–
38	Leguminosae-Papilionoideae	*Dalbergia cultrata* Graham ex Benth.	x	–
39	Leguminosae-Papilionoideae	*Pterocarpus macrocarpus* Kurz.	x	–
40	Leguminosae-Papilionoideae	*Vigna* sp.	x	–
41	Leguminosae	Unknown sp. 2	–	x
42	Lythraceae	*Lagestroemia macrocarpa* Wall.	x	x
43	Malvaceae	*Colona auriculata* (Desv.) Craib	–	x
44	Malvaceae	*Sida cordifolia* L.	x	–
45	Melastomataceae	*Osbeckia chinensis* L.	x	x
46	Myrtaceae	*Syzygium cumini* (L.) Skeels	x	–
47	Oleaceae	*Jasminum grandiflorum* (L.) Kobuski	x	x
48	Ranunculaceae	*Clematis meyeniana* Walp.	–	x
49	Rubiaceae	*Catunaregam tomentosa* (Blume ex DC) Tirveng	–	x
50	Rubiaceae	*Metadina trichotoma* (Zoll. Ex Merr.) Bakh.f.	x	–
51	Rubiaceae	*Paederia linearis* Hook. F.	x	–

Table 1 (Continued)

No.	Family	Botanical Name	B	UB
52	Rubiaceae	*Spermacoce pusilla* Wall.	x	x
53	Scrophulariceae	Unknown sp.1	x	–
54	Stereuliaceae	*Helicteres angustifolia* L.	–	x
55	Zingiberaceae	*Curcuma plicata* Wall.	x	–

Species Composition of seedlings

In the 20 seedlings plots there were 18 species from 11 different families were found. In burnt area , 12 species from 10 different families were found. In unburnt area, 9 species from 7 different families were found as shown in table 2.

Table 2 Species composition of seedlings

No.	Family	Botanical Name	B	UB
1	Anacardiaceae	*Lannea coromandelica* (Houtt.) Merr.	x	–
2	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	x	x
3	Bignoniaceae	*Fernandoa adenophylla* (Wall. ex G.Don) Steenis	x	–
4	Combretaceae	*Terminalia alata* Heyne.ex Roth	x	–
5	Combretaceae	*Terminalia chebula* Retz	x	–
6	Combretaceae	*Terminalia mucronata* Craib & Hutch.		x
7	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	–	x
8	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	x	–
9	Euphorbiaceae	*Aporosa villosa* (Wall. ex Lindl.) Baill.	x	x
10	Euphorbiaceae	*Croton hutchinsonianus* Hosseus	–	x
11	Guttiferae	*Cratoxylum formosum* (Jack) Dyer	x	–
12	Labiatae	*Vitex penuncularis* Wall ex Schauer	x	–
13	Labiatae	*Vitex limonifolia* Wall.	–	x

Table 2 (Continued)

No.	Family	Botanical Name	B	UB
14	Leguminosae-Caesalpinioideae	*Bauhinia saccocalyx* Pierre	–	x
15	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	x	x
16	Leguminosae-Papilionoideae	*Pterocarpus macrocarpus* Kurz.	x	–
17	Tiliaceae	*Grewia eriocarpa* Juss.	x	–
18	Tiliaceae	*Grewia hirsuta* Vahl	–	x

Species Composition of Saplings

In the 20 sapling plots, 12 species from 8 different families were found. In burnt area p, 8 species from 5 different families were found. In unburnt area , 5 species from 5 different families were found as shown in table 3.

Table 3 Species composition of saplings

No.	Family	Botanical Name	B	UB
1	Combretaceae	*Terminalia alata* Heyne.ex Roth	x	–
2	Combretaceae	*Terminalia mucronata* Craib & Hutch.	x	x
3	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	–	x
4	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	x	–
5	Dipterocarpaceae	*Shorea siamensis* Miq.	x	–
6	Ebenaceae	*Diospyros ehretioides* Wall. ex G.Don	x	–
7	Flacourtiaceae	*Casearia grewifolia* Vent.	–	x
8	Lauraceae	*Beilschmiedia fagifolia* Nees	–	x
9	Leguminosae-Caesalpinioideae	*Sindora siamensis* Teijsm.& Miq.	x	–
10	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	x	–
11	Rubiaceae	*Gardenia obtusifolia* Roxb. ex Kurz	–	x
12	Rubiaceae	*Metadina trichotoma* (Zoll. Ex Merr.) Bakh.f.	x	–

Species Composition of Trees

In all 10 tree plots, 29 species from 16 different families were found. In burnt area plots, 14 species from 9 different families were found. In unburnt area plots, 22 species from 12 different families were found as shown in table 4.

Table 4 Species composition of trees

No.	Family	Botanical name	B	UB
1	Anacardiaceae	*Buchanania lanzan* Spreng.	x	x
2	Anacardiaceae	*Gluta usitata* (Wall.) Ding Hou	-	x
3	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	x	x
4	Bignoniaceae	*Heterophragma sulfureum* Kurz.	x	-
5	Combretaceae	*Terminalia alata* Heyne.ex Roth	x	x
6	Combretaceae	*Terminalia chebula* Retz	x	-
7	Combretaceae	*Terminalia mucronata* Craib & Hutch.	x	x
8	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	-	x
9	Dipterocarpaceae	*Dipterocarpus obtusifolius* Teijsm.ex Miq.	-	x
10	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.	-	x
11	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	x	x
12	Dipterocarpaceae	*Shorea siamensis* Miq.	x	x
13	Ebenaceae	*Diaspyros ehretioides* Wall. ex G.Don	-	x
14	Euphorbiaceae	*Antidesma ghaesembilla* Gaertn.	-	x
15	Euphorbiaceae	*Aporosa villosa* (Wall. ex Lindl.) Baill.	-	x
16	Euphorbiaceae	*Phyllanthus emblica* L.	-	x
17	Flacourtiaceae	*Casearia grewifolia* Vent.	-	x
18	Labiatae	*Vitex peduncularis* Wall ex. Shauer.	-	x
19	Lauraceae	*Beilschmiedia fagifolia* Nees.	-	x
20	Lecythidaceae	*Careya arborea* Roxb.	-	x
21	Leguminosae-Caesalpiniodeae	*Bauhinia saccocalyx* Pierre	-	x
22	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	x	x
23	Leguminosae-Papilionoideae-	*Dalbergia cultrata* Graham ex Benth.	-	x
24	Leguminosae-Papilionoideae	*Dalbergia oliveri* Gamble	-	x
25	Leguminosae-Papilionoideae	*Pterocarpus macrocarpus* Kurz.	x	-

Table 4 (Continued)

No.	Family	Botanical name	B	UB
26	Loganiaceae	*Strychnos nux-vomica* L.	x	-
27	Ochnaceae	*Ochna intergerrima (*Lour.) Merr.	x	-
28	Rubiaceae	*Gardenia obtusifolia* Roxb. ex Kurz	x	-
29	Rubiaceae	*Mitragyna rotundifolia* (Roxb.) Kuntze	x	-

Importance Value Index (IVI)

Ground Flora

In the ground flora plots the IVI was calculated by summing up the relative frequency and relative dominance. the top five with the highest IVI in the burnt area were;. *Heteropogon triticeus* (R.Br.) Stapf ex Craib (30.1), *Vetiveria nemoralis* (L.) Nash (21.9), *Chromolaena odorata* (L.) King & H. Rob (19.0), *Cyperus cyperoides* (L.) O. Kuntze (10.4) and *Lagestroemia macrocarpa* Wall ex Kurz (10.1). The top five species with highest IVI in the unburnt area were; *Polyalthia debilis* (Pierre) Finet & Gagnep. (38.4), *Heteropogon triticeus* (R.Br.) Stapf ex Craib (21.9), *Panicum maximum* Jacq. (15.9), *Spilanthes iabadicensis* A.H. Moore (14.6), *Vetiveria nemoralis* A. Camus (L.) Nash (14.4). The species composition and IVI of ground flora are shown in table 5 and figure 8. The photographs of dominant species found in burnt and unburnt areas with high IVI are shown in figure 9 and 10.

Table 5 The species Importance Value Index of ground flora

NO.	IVI	Burnt Area	IVI	Unburnt Area
1	30.1	*Heteropogon triticeus* (R.Br.) Stapf ex Craib	38.4	*Polyalthia debilis* (Pierre) Finet & Gagnep.
2	21.9	*Vetiveria nemoralis* A. Camus	21.9	*Heteropogon triticeus* (R.Br.) Stapf ex Craib
3	19.0	*Chromolaena odorata* (L.) R.M. King & H. Rob.	15.9	*Panicum maximum* Jacq.

Table 5 (Continued)

NO.	IVI	Burnt Area	IVI	Unburnt Area
4	10.4	*Cyperus cyperoides* (L.) Kuntze	14.6	*Spilanthes iabadicensis* A.H. Moore
5	10.1	*Lagestroemia macrocarpa* Wall.	14.4	*Vetiveria nemoralis* A. Camus
6	8.2	*Holarrhena curtisii* King & Gamble	12.1	*Chromolaena odorata* (L.) R.M. King & H. Rob.
7	7.8	*Vigna sp*	9.8	*Casearia grewifolia* Vent.
8	7.7	*Sida cordifolia* L.	6.6	*Cyrtococcum patens* (L.) A. Camus
9	7.6	*Themeda triandra* Forssk. G	6.5	*Praxelis clematidea* R.M. King& H. Rob.
10	7.0	*Osbeckia chinensis* L.	5.7	*Cyperus cyperoides* (L.) Kuntze
11	5.7	*Jasminum grandiflorum* (L.) Kobuski	5.2	*Elephantopus scaber* L.
12	5.4	*Pterocarpus macrocarpus* Kurz.	4.5	*Commelina diffusa* Burm.f
13	5.2	*Sacciolepis turgida* Ridl.	4.2	*Barringtonia acutangula* (L.) Gaertn.
14	4.6	*Pogostemon quadrifolius* Kuntze.	4.0	*Eragrostis atrovirens* (Desf.) Steud.
15	3.9	*Imperata cylindrica* (L.) P.Beauv.	3.9	*Cyperus haspan* L.
16	3.7	*Syzygium cumini* (L.) Skeels	3.5	*Xylia xylocarpa* (Roxb.) Taub.
17	3.6	Unknown sp1	3.3	Unknown sp 2
18	3.6	*Uvaria argentea* Blume	2.5	*Erythroxylum cambodianum* Pierre
19	3.4	*Shorea obtusa* Wall.ex Blume	2.5	*Spermacoce pusilla* Wall.
20	3.2	*Pennisetum polystachion* (L.) Schult. Schult.	2.4	*Croton hutchinsonianus* Hosseus
21	2.9	*Costus speciosus* (Koen) Sm.	1.7	*Careya sphaerica* Roxb.
22	2.4	*Setaria parviflora* (Poir.) Kerguelen	1.7	*Litsea glutinosa* (Lour.) C.B.Rob.
23	2.4	*Curcuma plicata* Wall.	1.6	*Helicteres angustifolia* L.
24	2.1	*Xylia xylocarpa* (Roxb.) Taub.	1.5	*Jasminum grandiflorum* (L.) Kobuski
25	1.9	*Terminalia mucronata* Craib & Hutch.	1.5	*Clematis meyeniana* Walp.

Table 5 (Continued)

NO.	IVI	Burnt Area	IVI	Unburnt Area
26	1.9	*Praxelis clematidea* R.M. King& H. Rob.	1.5	*Murdannia spirata* (L.) G. Bruckn.
26	1.9	*Praxelis clematidea* R.M. King& H. Rob.	1.5	*Murdannia spirata* (L.) G. Bruckn.
27	1.9	*Croton hutchinsonianus* Hosseus	1.3	*Beilschmiedia fagifolia* Nees
28	1.7	*Metadina trichotoma* (Zoll. Ex Merr.) Bakh.f.	1.2	*Oplismenus compositus* (L.) P.Beauv.
29	1.6	*Diplacrum caricinum* R.Br.	1.2	*Catunaregam tomentosa* (Blume ex DC) Tirveng.
30	1.5	*Dalbergia cultrata* Graham ex Benth.	1.2	*Colona auriculata* (Desv.) Craib
31	1.5	*Commelina diffusa* Burm.f.	1.2	*Osbeckia chinensis* L.
32	1.5	*Paederia linearis* Hook. f.	1.2	*Fimbriastylis sp*
33	1.5	*Fernandoa adenophylla* (Wall. ex G.Don) Steenis	1.2	*Markhamia stipulata* Seem.
34	1.5	*Cyrtococcum patens* (L.) A. Camus		
35	1.4	*Spermacoce pusilla* Wall.		

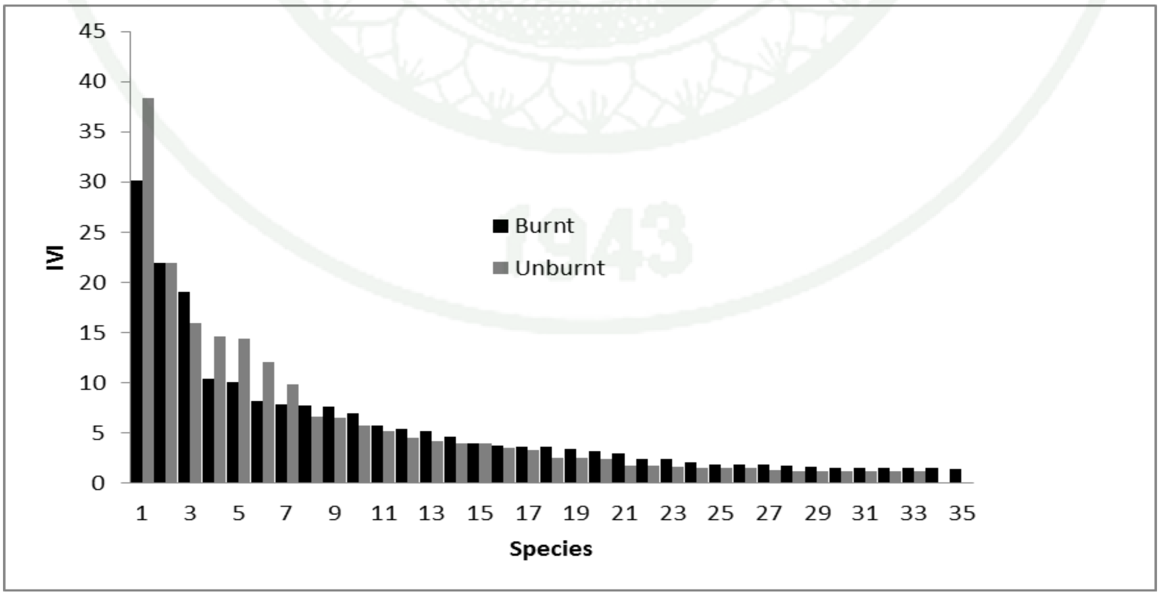

Figure 8 The species and IVI of ground flora shown as in table 5.

1. *Heteropogon triticeus* (R.Br.) Stapf ex Craib

2. *Vetiveria nemoralis* A. Camus

3. *Chromolaena odorata* (L.) R.M. King & H. Rob.

4. *Cyperus cyperoides* (L.) Kuntze

5. *Lagestroemia macrocarpa* Wall.

6. *Holarrhena curtisii* King & Gamble

Figure 9 The dominant species of ground flora found in a burnt area with highest IVI.

Source: Plants photographed by T. Methula (2014) and M. Poopath (2014).

1. *Polyalthia debilis* (Pierre) Finet & Gagnep.

2. *Heteropogon triticeus* (R.Br.) Stapf ex Craib

3. *Panicum maximum* Jacq.

4. *Spilanthes iabadicensis* A.H. Moore

5. *Vetiveria nemoralis* A. Camus

6. *Chromolaena odorata* (L.) R.M. King & H. Rob.

Figure 10 The dominant species of ground flora found in an unburnt area with highest IVI

Source: Plants photographed by T. Methula (2014) and M. Poopath (2014).

Seedlings

In the seedlings' plots, the IVI was calculated by summing up the relative density, relative frequency and relative dominance, the top five species with the highest IVI in the burnt area are; *Shorea obtusa* (106.2), *Polyalthia debilis* ((40.2), *Xylia xylocarpa* (26.5), *Dillenia obovata* (24.2), *Pterocarpus macrocarpus* (22.1). The top five species with the highest IVI in an unburnt area are; *Polyalthia debilis* (120.3), *Terminalia mucronata* (53.2), *Croton hutchinsonianus* (26.7), *Dillenia obovata* (25.2) and *Aporosa villosa* (19.1). The species composition and IVI are shown in on table 6 and figure 11. The photographs of dominant species found in burnt and unburnt areas with high IVI are shown in figure 12 and 13 below.

Table 6 The species Importance Value Index (IVI) of seedlings

NO.	IVI	Burnt Area	IVI	Unburnt Area
1	106.2	*Shorea obtusa* Wall.ex Blume	120.3	*Polyalthia debilis* (Pierre) Finet & Gagnep.
2	40.2	*Polyalthia debilis* (Pierre) Finet & Gagnep.	53.2	*Terminalia mucronata* Craib & Hutch.
3	26.5	*Xylia xylocarpa* (Roxb.) Taub.	26.7	*Croton hutchinsonianus* Hosseus
4	24.2	*Dillenia obovata* (Blume) Hoogland	25.2	*Dillenia obovata* (Blume) Hoogland
5	22.1	*Pterocarpus macrocarpus* Kurz.	19.1	*Aporosa villosa* (Wall. ex Lindl.) Baill.
6	20.1	*Lannea coromandelica* (Houtt.) Merr.	16.1	*Xylia xylocarpa* (Roxb.) Taub.
7	16.4	*Grewia eriocarpa* Juss.	13.7	*Grewia hirsuta* Vahl
8	9.6	*Terminalia alata* Heyne.ex Roth	13.2	*Vitex limonifolia* Wall.
9	9.6	*Cratoxylum formosum* (Jack) Dyer.	12.0	*Bauhinia saccocalx* Pierre
10	9.0	*Fernandoa adenophylla* (Wall. ex G.Don) Steenis		
11	8.4	*Vitex penuncularis* Wall ex Schauer		
12	7.8	*Terminalia chebula* Retz		

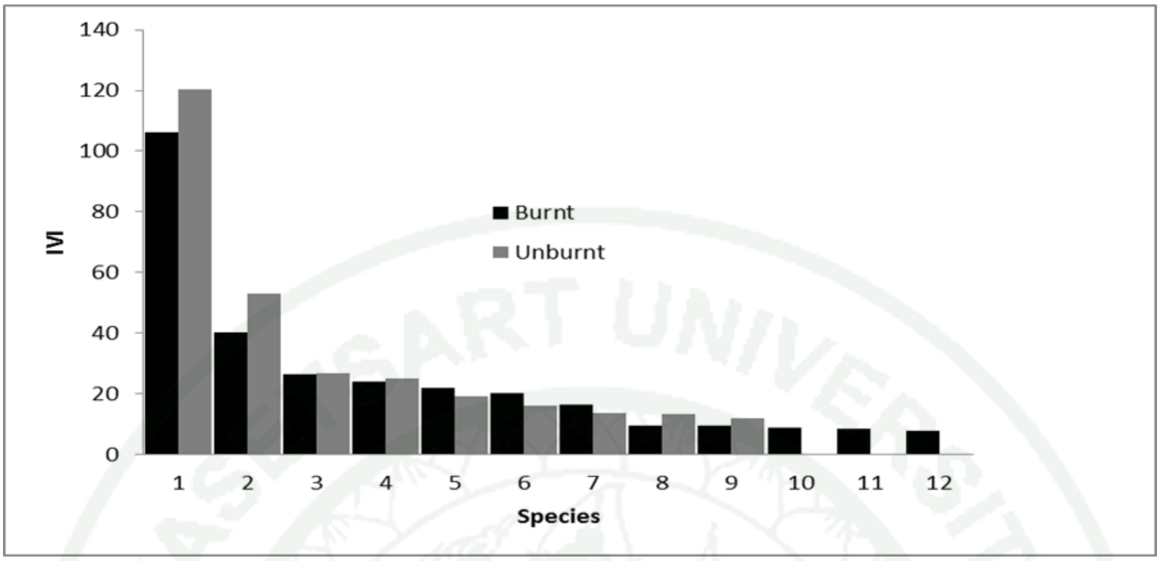

Figure 11 The species and IVI of seedlings as shown in table 6.

1. *Shorea obtusa* Wall.ex Blume.

2. *Polyalthia debilis* (Pierre) Finet & Gagnep.

3. *Xylia xylocarpa* (Roxb.) Taub.

4. *Dillenia obovata* (Blume) Hoogland

5. *Pterocarpus macrocarpus* Kurz.

6. *Lannea coromandelica* (Houtt.) Merr.

Figure 12 The dominant species of seedlings found in a burnt area with highest IVI.

Source: Plants photographed by T. Methula (2014) and M. Poopath (2014).

1. *Polyalthia debilis* (Pierre) Finet & Gagnep.

2. *Terminalia mucronata* Craib & Hutch.

3. *Croton hutchinsonianus* Hosseus

4. *Dillenia obovata* (Blume) Hoogland

5. *Aporosa villosa* (Wall. ex Lindl.) Baill.

6. *Xylia xylocarpa* (Roxb.) Taub.

Figure 13 The dominant species of seedlings found in an unburnt area with highest IVI.

Source: Plants photographed by T. Methula (2014) and M. Poopath (2014).

Sapling

The IVI for saplings was calculated by summing up the relative frequency, relative dominance and relative density. The top five saplings with the highest IV in a burnt area are; *Xylia xylocarpa* (63.8), *Shorea obtusa* (60.9), *Sindora siamensis* (42.9), *Terminalia alata* (39.6) and *Diospyros ehretioides* (35.7). The top five saplings with the highest IVI in an unburnt area are; *Terminalia mucronata* (82.3), *Dillenia obovata* (73.9), *Casearia grewifolia* (52.5), *Gardenia obtusifolia* (48.6) and *Beilschmiedia fagifolia* (42.2). The species composition and IVI are shown on table 7 and figure 14. The photographs of dominant species found in burnt and unburnt areas with high IVI are shown in figure 15 and 16 below.

Table 7 The species Importance Value Index (IVI) of saplings

NO	**IVI**	**Burnt Area**	**IVI**	**Unburnt Area**
1	63.8	*Xylia xylocarpa* (Roxb.) Taub.	82.3	*Terminalia mucronata* Craib & Hutch.
2	60.9	*Shorea obtusa* Wall.ex Blume	73.9	*Dillenia obovata* (Blume) Hoogland
3	42.9	*Sindora siamensis* Teijsm.& Miq.	52.5	*Casearia grewifolia* Vent.
4	39.6	*Terminalia alata* Heyne.ex Roth	48.6	*Gardenia obtusifolia* Roxb. ex Kurz
5	35.7	*Diospyros ehretioides* Wall. ex G.Don	42.2	*Beilschmiedia fagifolia* Nees
6	19.2	*Terminalia mucronata* Craib & Hutch.		
7	19.1	*Shorea siamensis* Miq.		
8	18.6	*Metadina trichotoma* (Zoll. Ex Merr.) Bakh.f.		

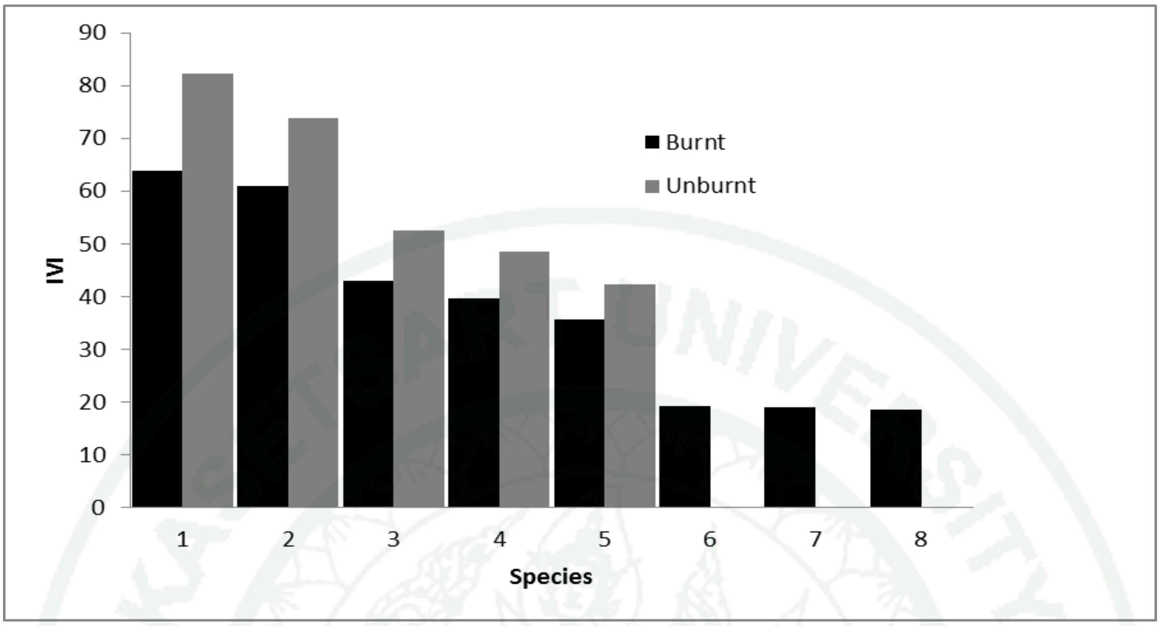

Figure 14 The species IVI of saplings as shown in table 7.

1. *Xylia xylocarpa* (Roxb.) Taub.

2. *Shorea obtusa* Wall.ex Blume

3. *Sindora siamensis* Teijsm.& Miq.

4. *Terminalia alata* Heyne.ex Roth

5. *Diospyros ehretioides* Wall. ex G.Don

6. *Terminalia mucronata* Craib & Hutch.

Figure 15 The dominant species of saplings found in a burnt area with highest IVI.

Source: Plants photographed by T. Methula (2014) and M. Poopath (2014).

1. *Terminalia mucronata* Craib & Hutch.

2. *Dillenia obovata* (Blume) Hoogland

3. *Casearia grewifolia* Vent.

4. *Gardenia obtusifolia* Roxb. ex Kurz

5. *Beilschmiedia fagifolia* Nees

Figure 16 The sapling species found in an unburnt area.

Source: Plants photographed by T. Methula (2014) and M. Poopath (2014).

Trees

The IVI for trees was calculated by summing up the relative frequency, relative dominance and relative density. The species composition and IVI are shown in table 8 below. The species composition and IVI of trees are shown in figure 17.

Table 8 The species Importance Value Index (IVI) of trees

No.	IVI	Burnt Area	IVI	Unburnt Area
1	62.3	*Shorea siamensis* Miq.	39.6	*Dipterocarpus tuberculatus* Roxb.
2	59.4	*Xylia xylocarpa* (Roxb.) Taub.	37.3	*Terminalia mucronata* Craib & Hutch.
3	45.8	*Shorea obtusa* Wall.ex Blume	31.2	*Xylia xylocarpa* (Roxb.) Taub.
4	24.8	*Ochna intergerrima (*Lour.) Merr.	25.9	*Terminalia alata* Heyne.ex Roth.
5	19.0	*Polyalthia debilis* (Pierre) Finet & Gagnep.	20.1	*Buchanania lanzan* Spreng
6	15.8	*Terminalia mucronata* Craib & Hutch.	19.3	*Dillenia obovata* (Blume) Hoogland
7	14.6	*Mitragyna rotundifolia* (Roxb.) Kuntze	15.8	*Shorea obtusa* Wall.ex Blume
8	12.8	*Buchanania lanzan* Spreng.	15.3	*Antidesma ghaesembilla* Gaertn.
9	11.2	*Strychnos nux-vomica* L.	13.5	*Polyalthia debilis* (Pierre) Finet & Gagnep.
10	8.7	*Gardenia obtusifolia* Roxb. ex Kurz	11.0	*Gluta usitata* (Wall.) Ding Hou
11	6.8	*Pterocarpus macrocarpus* Kurz.	10.3	*Dalbergia cultrata* Graham ex Benth.
12	6.7	*Heterophragma sulfureum* Kurz.	9.1	*Beilschmiediia fagifolia* Nees.
13	6.1	*Terminalia alata* Heyne.ex Roth	8.1	*Dalbergia oliveri* Gamble
14	6.1	*Terminalia chebula* Retz	7.5	*Shorea siamensis* Miq.
15			6.2	*Diaspyros ehretioides* Wall. ex G.Don
16			5.8	*Dipterocarpus obtusifolius* Teijsm.ex Miq.
17			5.4	*Bauhinia saccocalx* Pierre
18			4.5	*Aporosa villosa* (Wall. ex Lindl.) Baill.

Table 8 (Continued)

No.	IVI	Burnt Area	IVI	Unburnt Area
19			3.9	*Vitex peduncularis* Wall ex. Shauer.
20			3.8	*Phyllanthus emblica* L.
21			3.5	*Careya arborea* Roxb.
22			3.1	*Casearia grewifolia* Vent.

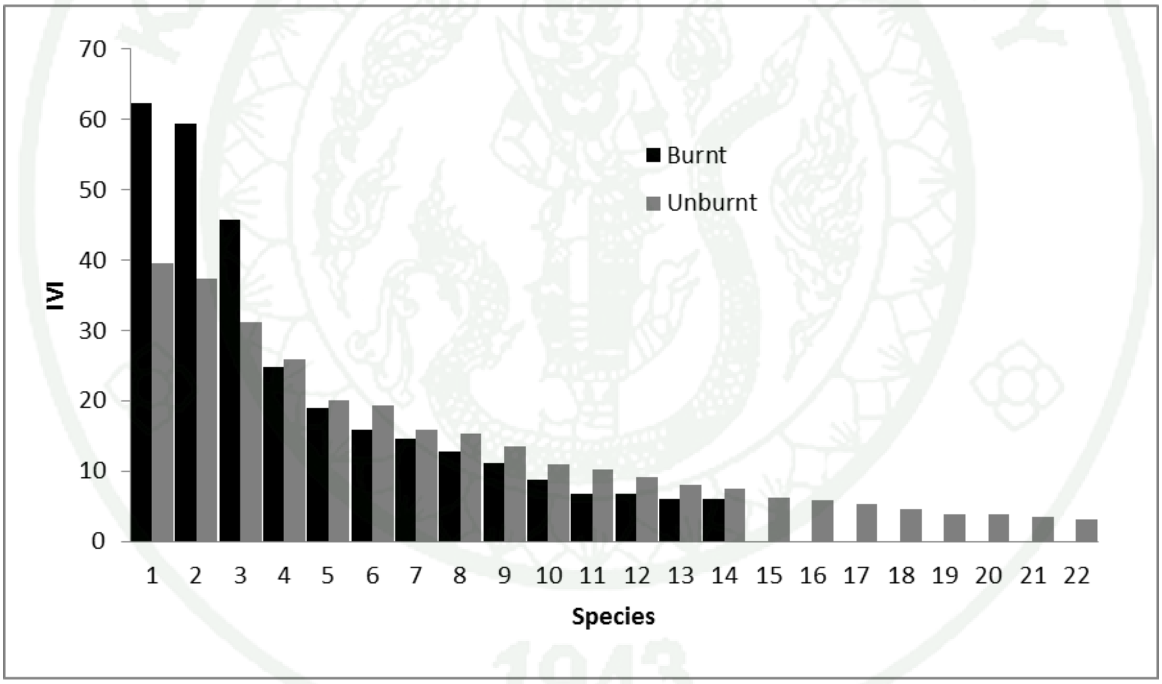

Figure 17 Species and IVI of trees as shown in table 8.

The importance value percentage of ground flora shows that the top five species consist of 45.8% of the total IVI in burnt area and 52.7% of the total IVI in unburnt area. For the top five seedlings, they comprise of 73.1% of the total IVI in burnt area and 81.5% of the total IVI in unburnt area. For saplings, the first five species in burnt area comprise of 81% of the total IVI and in the burnt area there were 5 species which made up 100% of the total IVI in unburnt area as shown in figure 18.

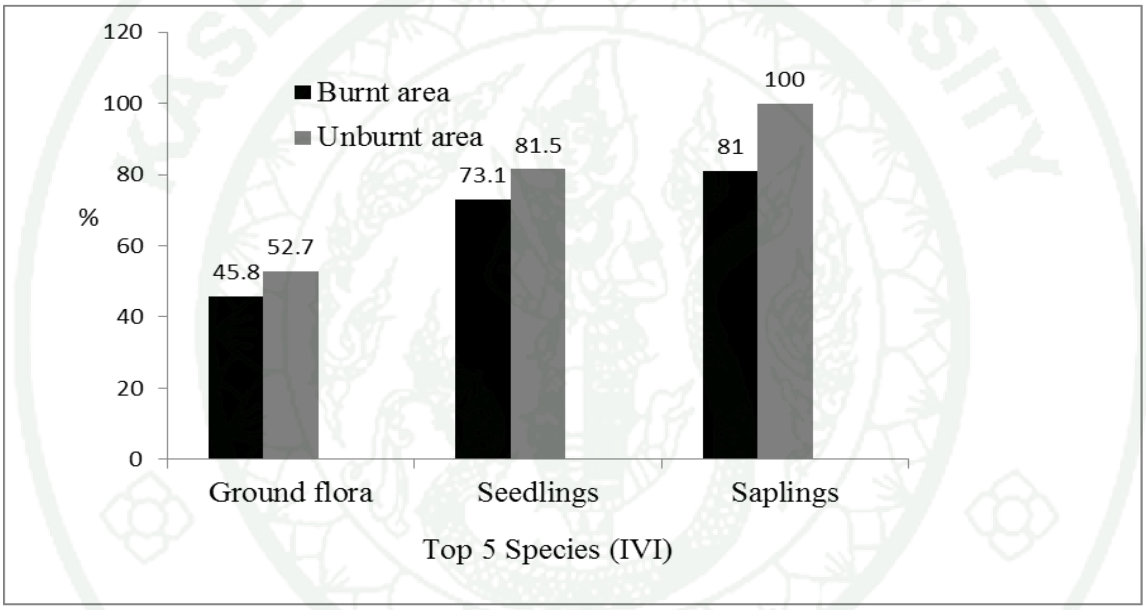

Figure 18 The IVI of the five most dominant species of ground flora, seedlings and saplings.

Plant Family Composition and Importance Value Index

Ground flora

There were 21 plant families recorded for the ground flora species in burnt area and 19 in unburnt area. The Gramineae family had the highest IVI for ground flora families found in both burnt areas (75.7) and unburnt areas (64.1). Table 9 below shows the family importance value index and the number of species that made up those values in both burnt and unburnt areas.

Table 9 The family composition and IVI of ground flora

	Burnt Area			Unburnt Area		
	Family	**# of species**	**IVI**	**Family**	**# of species**	**IVI**
1	Gramineae	8	75.7	Gramineae	6	64.1
2	Compositae	2	20.9	Compositae	4	38.5
3	Leguminosae	4	16.9	Annonaceae	1	38.4
4	Cyperaceae	2	12.1	Cyperaceae	3	10.8
5	Lythraceae	1	10.1	Flacourtiaceae	1	9.8
6	Apocynaceae	1	8.2	Leguminosae	2	6.7
7	Malvaceae	1	7.7	Commelianaceae	2	5.9
8	Melastomataceae	1	7.0	Lecythidaceae	2	5.9
9	Oleaceae	1	5.7	Rubiaceae	2	3.7
10	Labiatae	1	4.6	Lauraceae	2	3.0
11	Rubiaceae	3	4.6	Erythroxylaceae	1	2.5
12	Myrtaceae	1	3.7	Euphorbiaceae	1	2.4
13	Scrophulariaceae	1	3.6	Sterculiaceae	1	1.6
14	Annonaceae	1	3.6	Oleaceae	1	1.5
15	Dipterocarpaceae	1	3.4	Ranunculaceae	1	1.5
16	Costaceae	1	2.9	Malvaceae	1	1.2
17	Zingiberaceae	1	2.4	Bignoniaceae	1	1.2
18	Combretaceae	1	1.9	Melastomataceae	1	1.2
19	Euphorbiaceae	1	1.9			
20	Commelianaceae	1	1.5			
21	Bignoniaceae	1	1.5			

Seedlings

In burnt area, there were 10 families of seedlings recorded and 7 families in unburnt area. The family Dipterocarpaceae (106.2) had the highest importance value index for seedlings found in burnt area, and the family Annonaceae (120.3) had the highest importance value for seedling found in unburnt area as shown in table 10.

Table 10 The family composition and IVI of seedlings.

	Burnt Area			Unburnt Area		
	Family	**# of species**	**IVI**	**Family**	**# of species**	**IVI**
1	Dipterocarpaceae	1	106.2	Annonaceae	1	120.3
2	Leguminosae	2	48.6	Combretaceae	1	53.2
3	Annonaceae	1	40.2	Euphorbiaceae	2	45.8
4	Dilleniaceae	1	24.2	Leguminosae	2	28.1
5	Anacardiaceae	1	20.1	Dilleniaceae	1	25.2
6	Combretaceae	2	17.4	Tiliaceae	1	13.7
7	Tiliaceae	1	16.4	Labiatae	1	13.2
8	Guttiferae	1	9.6			
9	Bignoniaceae	1	9			
10	Labiatae	1	8.4			

Saplings

There were 5 plant families for saplings found in both burnt and unburnt areas. The family, Leguminosae (106.7) had the highest importance value index for saplings found in burnt area, and the family Combretaceae (82.3) had the highest importance value index for saplings found in unburnt area as shown in table 11.

Table 11 The family composition and IVI of Saplings

	Burnt Area			Unburnt Area		
	Family	**# of species**	**IVI**	**Family**	**# of species**	**IVI**
1	Leguminosae	2	106.7	Combretaceae	1	82.3
2	Dipterocarpaceae	2	80	Dilleniaceae	1	73.9
3	Combretaceae	2	58.8	Flacourtiaceae	1	52.5
4	Ebenaceae	1	35.7	Rubiaceae	1	48.6
5	Rubiaceae	1	18.6	Lauraceae	1	42.2

Trees

There were 9 plant families for trees found in burnt area and 12 families in unburnt area. The family, Dipterocarpaceae had the highest importance value index for trees found in both burnt and unburnt areas as shown in table 12.

Table 12 The family composition and IVI of trees.

No.	**Family**	**# of Plants**	**IVI**	**Family**	**# of plants**	**IVI**
1	Dipterocarpaceae	13	108.1	Dipterocarpaceae	19	68.7
2	Leguminosae	9	66.2	Combretaceae	36	63.2
3	Combretaceae	3	28.0	Leguminosae	26	55.0
4	Ochnaceae	4	24.8	Anacardiaceae	9	31.1
5	Rubiaceae	4	23.3	Euphorbiaceae	11	23.6
6	Annonaceae	4	19.0	Dilleniaceae	13	19.3
7	Anacardiaceae	2	12.8	Annonaceae	7	13.5
8	Loganiaceae	1	11.2	Lauraceae	5	9.1
9	Bignoniaceae	1	6.7	Ebenaceae	2	6.2
10				Labiatae	1	3.9
11				Lecythidaceae	1	3.5
12				Flacourtiaceae	1	3.1

Forest Structure: The vegetation data from the sampling plots (50 m x 10 m) including botanical name, number of species and height were used to construct the forest diagram for vegetation layer analysis.

In burnt area, there were 41 tree plants which consisted of 14 different species from 9 families. The top five tallest tree species were *Terminalia mucronata* Craib & Hutch., *Xylia xylocarpa* (Roxb.) Taub., *Shorea siamensis* Miq., *Shorea obtusa* Wall.ex Blume, *Strychnos nux-vomica* L. The families with most plants were; Dipterocarpaceae, Leguminosae, Ochnaceae, Rubiaceae and Combretaceae as shown in table 13. Figure 19 shows the forest profile diagram of burnt area.

Table 13 Tree family composition and species composition in the burnt area.

Family	Botanical Name	# of plants
Anacardiaceae	*Buchanania lanzan* Spreng.	2
Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	4
Bignoniaceae	*Heterophragma sulfureum* Kurz.	1
Combretaceae	*Terminalia alata* Heyne.ex Roth	1
Combretaceae	*Terminalia chebula* Retz	1
Combretaceae	*Terminalia mucronata* Craib & Hutch.	1
Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	6
Dipterocarpaceae	*Shorea siamensis* Miq.	7
Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	8
Leguminosae-Papilionoideae	*Pterocarpus macrocarpus* Kurz.	1
Loganiaceae	*Strychnos nux-vomica* L.	1
Ochnaceae	*Ochna intergerrima (*Lour.) Merr.	4
Rubiaceae	*Gardenia obtusifolia* Roxb. ex Kurz	2
Rubiaceae	*Mitragyna rotundifolia* (Roxb.) Kuntze	2

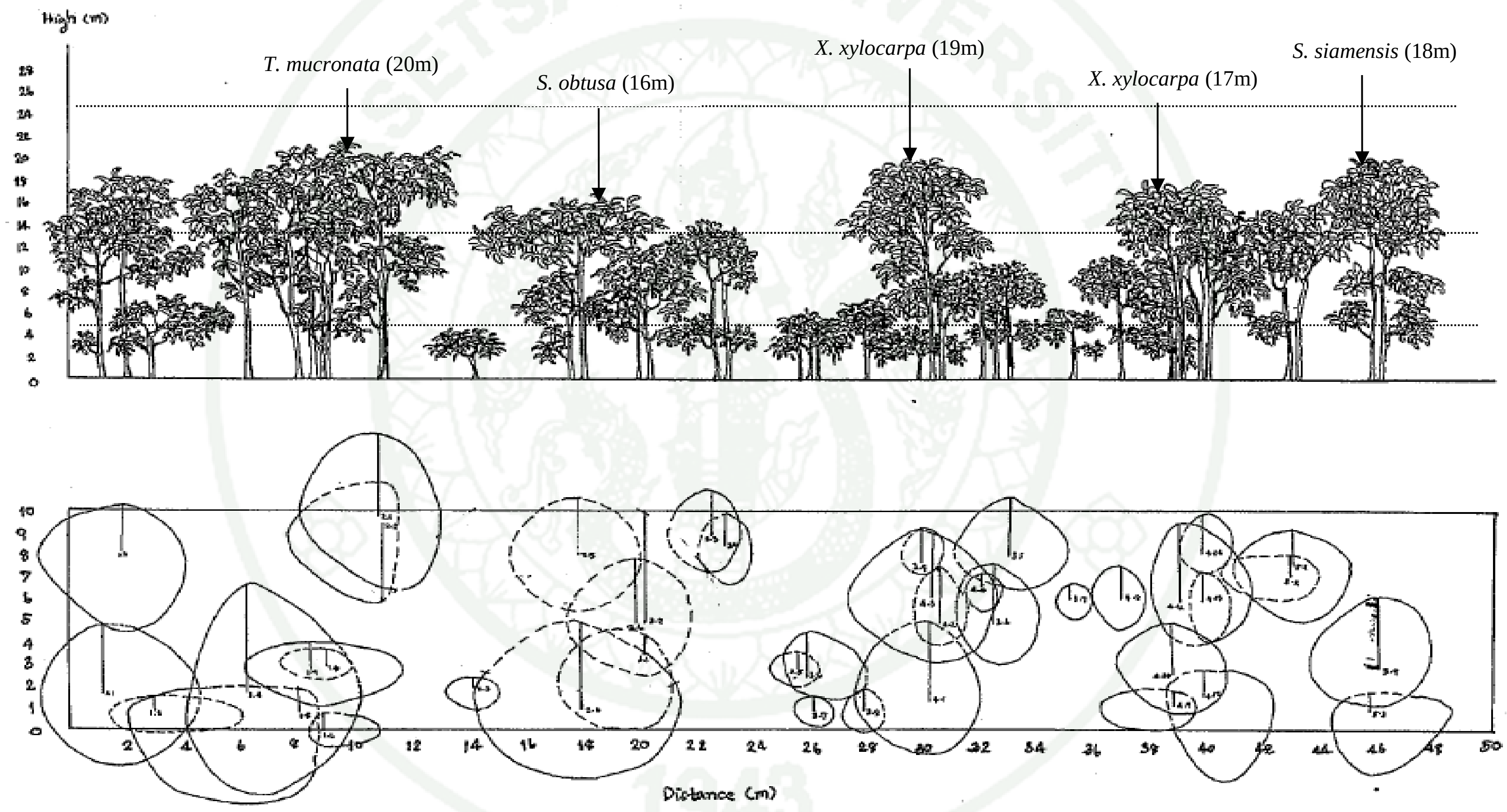

Figure 19 The forest profile diagram of burnt area.

In unburnt area, there were 131 tree plants which consisted of 22 different species from 12 families. The top five tallest tree species were *Dipterocarpus tuberculatus* Roxb., *Shorea siamensis* Miq., *Xylia xylocarpa* (Roxb.) Taub., *Dalbergia oliveri* Gamble and *Buchanania lanzan* Spreng. The families with most plants were; Combretaceae, Leguminosae, Dipterocarpaceae, Dilleniaceae and Anarcadiaceae as shown in table 14. Figure 20 shows the forest profile diagram of unburnt area.

Table 14 Tree family composition and species composition in the unburnt area.

Family	**Botanical Name**	**# of plants**
Anacardiaceae	*Buchanania lanzan* Spreng	8
Anacardiaceae	*Gluta usitata* (Wall.) Ding Hou	2
Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	8
Combretaceae	*Terminalia alata* Heyne.ex Roth.	15
Combretaceae	*Terminalia mucronata* Craib & Hutch.	22
Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	13
Dipterocarpaceae	*Dipterocarpus obtusifolius* Teijsm.ex Miq.	2
Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.	9
Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	5
Dipterocarpaceae	*Shorea siamensis* Miq.	3
Ebenaceae	*Diospyros ehretioides* Wall. ex G.Don	2
Euphorbiaceae	*Antidesma ghaesembilla* Gaertn.	8
Euphorbiaceae	*Aporosa villosa* (Wall. ex Lindl.) Baill.	2
Euphorbiaceae	*Phyllanthus emblica* L.	1
Flacourtiaceae	*Casearia grewifolia* Vent.	1
Labiatae	*Vitex peduncularis* Wall ex. Shauer.	1
Lauraceae	*Beilschmiediia fagifolia* Nees.	5
Lecythidaceae	*Careya arborea* Roxb.	1
Leguminosae-Caesalpiniodeae	*Bauhinia saccocalyx* Pierre	3
Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	15
Leguminosae-Papilionoideae	*Dalbergia cultrata* Graham ex Benth.	5
Leguminosae-Papilionoideae	*Dalbergia oliveri* Gamble	2

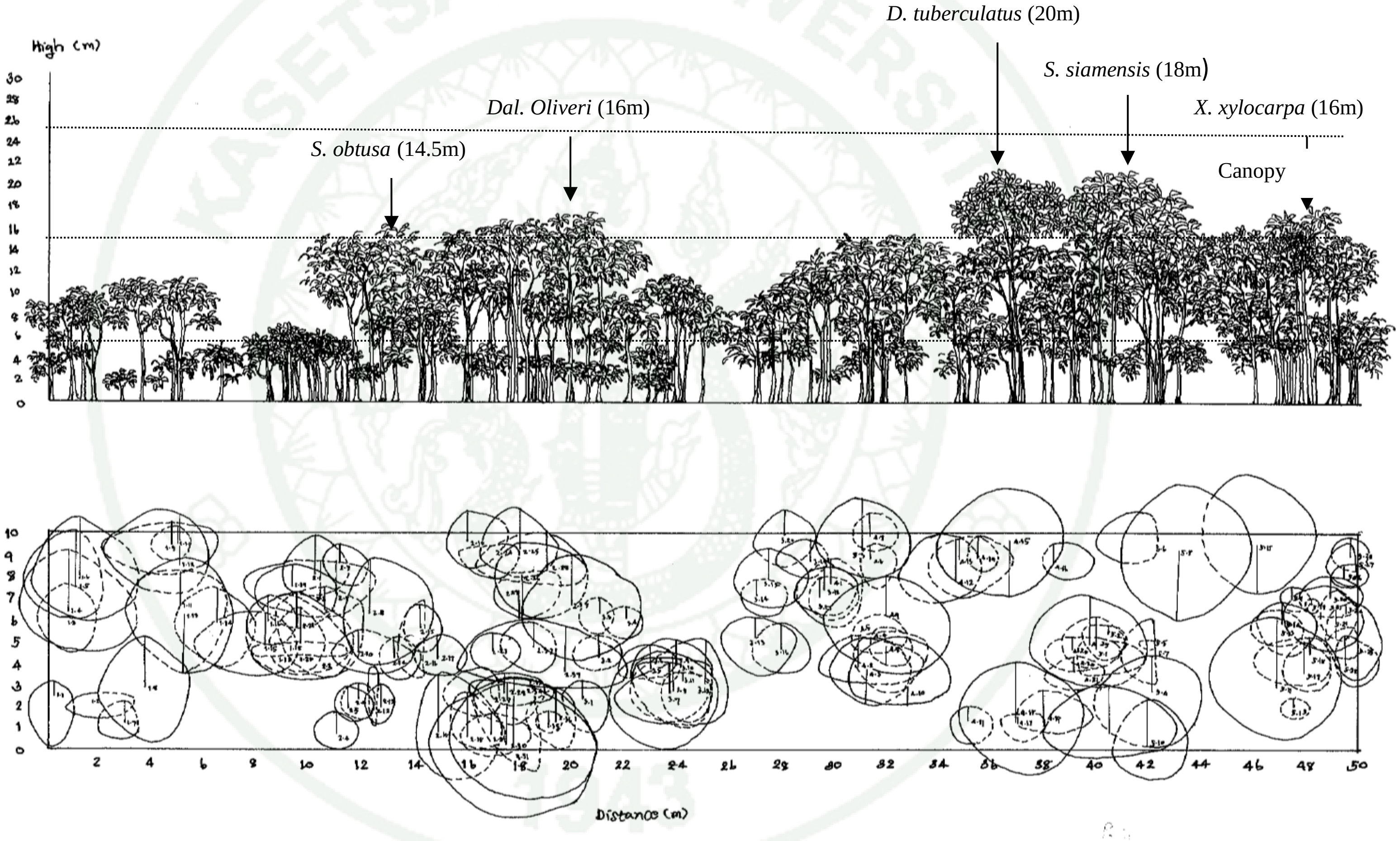

Figure 20 The forest profile diagram of the unburnt area

The total canopy percent cover for trees in burnt area was 19.4% and 22.5% in unburnt area. The top layer percent cover in burnt and unburnt areas was 75.6% and 35.9% respectively; the middle layer percent cover in burnt and unburnt areas was 23.5% and 55% respectively and the lowest layer percent cover in burnt and unburnt areas was 0.9% and 9.1% respectively.

The average height of the trees found in burnt area was 11.5 m, average DBH was 15.4 cm. In unburnt area the average height for the trees was 8.9 m, average DBH was 9.13 cm. For the tree species, there were 14 species found in burnt area and 22 species found in unburnt area, 7 species occurred in both burnt and unburnt areas as shown in figure 21 below.

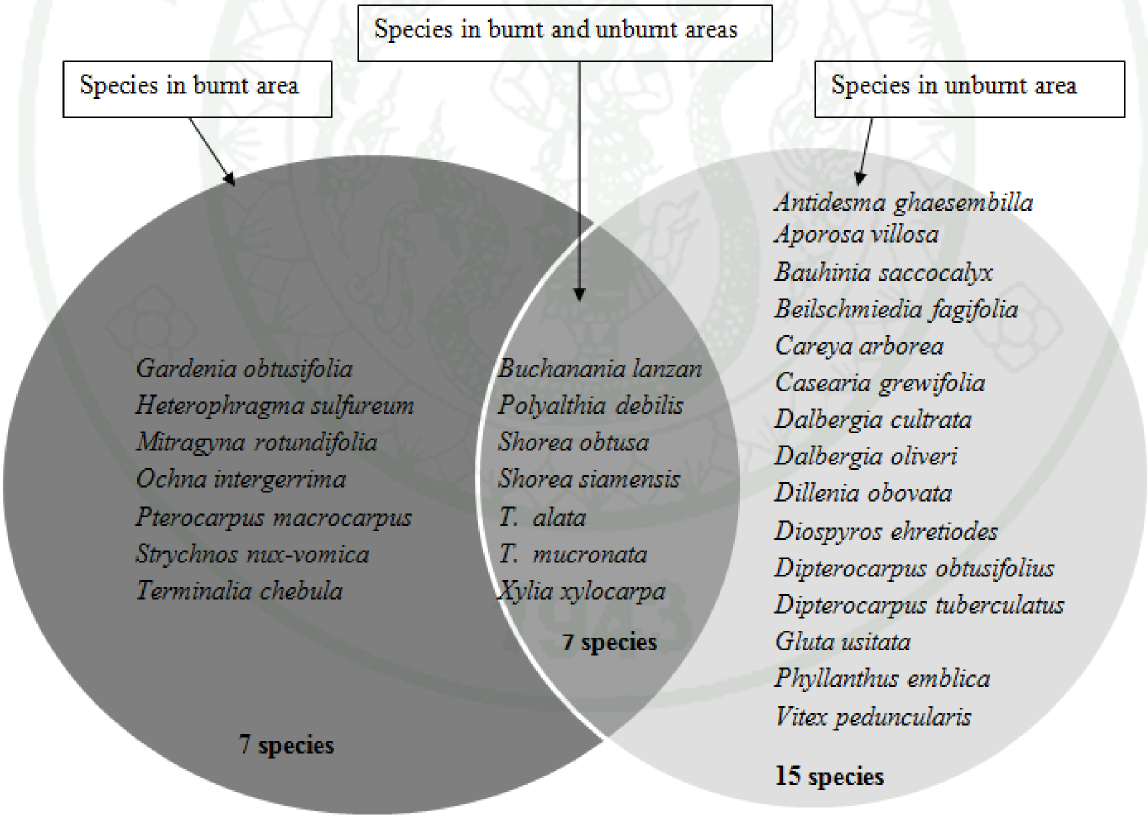

Figure 21 Species diversity of trees and shrubby trees in burnt and unburnt areas.

Species Diversity

For ground flora, the species diversity of Shannon-Weiner Index for the burnt area was 3.14 and for the unburnt area it was 3.18. For the seedlings, the species diversity of Shannon-Weiner index for burnt area was 2.39 and for the unburnt area it was 2.10. The species diversity for saplings in a burnt area was 2.02 and in an unburnt area it was 1.56 as shown in table 15.

Table 15 Shannon-Wiener Index

	Ground flora		**Seedlings**		**Saplings**	
	B	**UB**	**B**	**UB**	**B**	**UB**
Number of species	35	33	12	9	8	5
Species Diversity Index (H)	3.14	3.18	2.39*	2.10	2.02*	1.56
Evenness	0.88	0.91	0.96	0.96	0.97	0.97

*Significant difference at $p<0.05$

The species diversity for trees was 2.34 in a burnt area and 2.71 in an unburnt area as determined by the Shannon-Weiner index.

Species Richness

The species richness for ground flora, seedlings, saplings and trees was higher in the burnt areas than in the unburnt areas. The values of species richness are shown in table 16 below.

Table 16 Species richness of Menhinick's index

	Ground flora		**Seedlings**		**Saplings**		**Trees**	
	B	**UB**	**B**	**UB**	**B**	**UB**	**B**	**UB**
No. of species (S)	35	33	12	9	8	5	14	22
No. of individuals (N)	72	83	65	66	11	7	41	131
Sp richness (D)	4.1	3.6	1.5	1.1	2.7	1.9	2.2	1.9

Species Similarity

The species similarity was calculated using the Sorensen Index. The similarity of ground flora was 0.38; for the seedlings, the similarity was 0.29; for the saplings, the similarity was 0.15; and for trees the similarity was 0.38 as shown in table 17. The ground flora and trees had a higher similarity value compared to the other vegetation life forms.

Table 17 Species similarity by Sorensen index

	Ground flora	**Seedlings**	**Saplings**	**Trees**
No. of species in burnt area	35	12	8	14
No. of species in unburnt area	33	9	5	22
No. of species shared	13	3	1	7
Similarity Index	0.38	0.29	0.15	0.38

2. Soil properties

Soil samples were taken from two levels in both burnt and unburnt areas; 0-25 cm depth and 25-50 cm depth. The following soil elements were analysed; organic matter, pH, total nitrogen, available phosphorus, exchangeable potassium, exchangeable calcium, ash and moisture percentage. In burnt area, the pH, exchangeable potassium, exchangeable calcium, ash and moisture percentage were higher in the subsoil than surface soil. In unburnt area, organic matter, total nitrogen, available phosphorus, exchangeable calcium and ash percentage were higher in the surface soil than subsoil. Table 18 shows the quantities of the various soil elements that were analysed. In the deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sanctuary, soil textures are sandy loam at the surface and sandy clay-loam in the subsurface horizons (Bunyavejchewin *et al*., 2009).

Table 18 Soil chemical properties

Parameters analyzed	Burnt area (0-25 cm)	Unburnt area (0-25 cm)	Burnt area (25-50 cm)	Unburnt area (25-50 cm)
pH (1:1)	5.51	5.1	5.5	5.53
Organic matter %	0.93	0.46	0.56	0.2
Total N	0.03	0.06	0.02	0.04
Available P (mg/kg)	5.96	64.48	3.26	42.74
Exchangeable K (mg/kg)	39.82	17.5	41.78	18.12
Exchangeable Ca (mg/kg)	263	72.88	304.2	40.42
Ash%	2.56	1.49	5.16	0.99
Moisture %	1.03	0.97	4.02	1.1

3. Wildlife Abundance

The Herbivores abundance was determined by calculating the dung density and pellet group density. The dung density for Asian elephants in a burnt area was 60 dung/ha and 30 dung/ha in an unburnt area. The dung density for Banteng in a burnt area was 80 dung/ha and 60 dung/ha in an unburnt area. There was no gaur dung found in both burnt and unburnt areas. For the Sambar deer, the pellet group count density is 3250 pellet groups/ha in a burnt area and 500 pellet groups/ha in an unburnt area. The pellet group count density for the common barking deer in the burnt area is 750 pellet groups/ha and 250 pellet groups/ha as shown in table 19 below.

Table 19 Dung density and pellet group density

Species	Burnt Area Dung/Pellet density	Unburnt Area Dung/Pellet density
Asian elephant (*Elephas maximus* Linnaeus)	60 dung/ha*	30 dung/ha
Banteng (*Bos javanicus* D'Alton)	80 dung/ha*	60 dung/ha
Gaur (*Bos gaurus* Smith)	0 dung/ha	0 dung/ha
Sambar deer (*Cervus unicolor* Kerr)	3250 pellet groups/ha*	500 pellet groups/ha
Common barking deer (*Muntiacus muntjak* Zimmermann)	750 pellet groups/ha*	250 pellet groups/ha

*Significant difference at $p<0.05$

During the study, dung of Asian elephants, banteng and pellets of Sambar deer and common barking deer were found in the study area. There was no Gaur dung. Figure 22 shows the herbivores and figure 23 shows their dung and pellets.

1.Asian elephant (*Elephas maximus* Linnaeus)

2. Banteng (*Bos javanicus* D'Alton)

3. Sambar deer (*Cervus unicolor* Kerr)

4. Common barking deer (*Muntiacus muntjak* Zimmermann)

Figure 22 Wild herbivores of the DDF.

Source: Large herbivores photographed by N. Bhumpakphan (2014)

Figure 23 Dung and pellets found in the study area; (a) Asian elephant dung, (b) banteng dung, (c) common barking deer pellets, (d) Sambar deer pellets.

Discussion

1. Effects of Fire on Vegetation Species

1.1 Effects of Fire on Vegetation Species Composition

The existence of certain species in the Deciduous Dipterocarp Forest community largely depends on its regeneration under varied environmental conditions and common anthropogenic activities including burning have a tremendous effect on the regeneration of tree species (Prasad and Al-Sagher, 2012). Sagar et al. (2008) observed that the presence of several species as only understorey suggests that the ability of species recruitment may result from disturbance, of which fire would be one. In this study the same observations were made; it was observed that in a burnt area 14% of seedlings had appeared in the ground flora records and 25% of saplings had appeared as seedlings. In the unburnt area, 9% of seedlings had been noted in the ground flora plots and 25% of saplings had appeared as seedlings. Davies (1997) observed that small herbaceous plants with high light requirements for growth and seedling establishment are the most affected by fire suppression. This explains why there was more recruitment and regeneration in the burnt area than in the unburnt area.

This study showed that effects of fire resulted in higher species composition for ground flora, which was shown by a higher species richness of ground flora in the burnt area compared to the unburnt area. Based on the number of species, there were differences in ground flora vegetation composition between a burnt area and an unburnt area. There were more ground flora species found in burnt area (35) than in unburnt area (33) and; 22 species were found only in a burnt area and not in unburnt area, and 20 species were found only in an unburnt area and not found in burnt area. The study also showed that the number of seedlings species found in the burnt area was higher than in the unburnt area, 12 species of seedlings were found in the burnt area and 9 species of seedlings were found in the unburnt area, 9 species were only found in burnt area and 6 species were only found in an unburnt area. The results also showed that the number of saplings species found in the burnt area was higher than in the unburnt area. In the burnt area, there were 8 species of saplings and 5 species of saplings in the unburnt area, 7 species were found only in a burnt area and 4 species were found only in an unburnt area. Fang (2008) concluded that species composition of plants after fire disturbance was higher than areas with no disturbance and this could be due to the emergence of new species.

In the study it was also observed that the trend in terms of species richness in burnt area was high for all the vegetation classes studied compared to the unburnt areas. The species richness index (Menhinick) was found to be high in the burnt area than in an unburnt area; for ground flora in the burnt area it was 4.1 and 3.6 in the unburnt area, for seedlings in the burnt area it was 1.5 and 1.1 in the unburnt area and for saplings in the burnt area it was 2.7 and 1.9 in the unburnt area. Sutumo and Fardila (2013) also made the same observation that the species composition was higher in burnt areas than in unburnt areas, and burnt sites recorded higher species richness than unburnt sites.

In this study, the Gramineae species, *Imperata cylindrica*, *Pennisetum polystachion*, *Sacciolepis turgida*, *Setaria parviflora*, *Themeda triandra* appeared only in the burnt area, Sutumo and Fardila (2013) in their study also made a similar observation whereby they noted that some species only occur in a burnt area and concluded that the intolerance to shade is the reason some particular species do not occur in an unburnt area.

Monroe and Converse (2006) state that the understory fires are generally non-lethal to the dominant vegetation. This could be the reason that in this study it was observed that in the five most dominant species of ground flora according to the importance value index, 2 species (*Heteropogon triticeus* and *Vetiveria nemoralis*) appeared in both burnt and unburnt areas and three plant families (Gramineae, Compositae and Cyperaceae) were represented amongst the five most dominant families in both burnt and unburnt areas. In the five most important species of seedlings, 2 species (*Polyalthia debilis* and *Dillenia obovata*) appeared in both burnt and unburnt areas, and two plant families (Leguminosae and Dilleniaceae) were represented amongst the five most dominant families in both burnt and unburnt areas. Amongst the top five dominant species of saplings in burnt and unburnt area, there were no species that appeared in both areas; only 2 plant families (Combretaceae and Rubiaceae) were represented among the top ranked families in both burnt and unburnt areas. This shows that understory fire is non-lethal to the dominant vegetation as stated by Monroe and Converse (2006).

To analyse the dominance of plant species, the top five species of each site based on higher IVI were selected. In the study, the importance values index revealed that for the ground flora in burnt area the five most dominant species comprise 45.8% of the total IVI percentage (*Heteropogon triticeus* (R.Br.) Stapf ex Craib, *Vetiveria nemoralis* A. Camus, *Chromolaena odorata* (L.) King & H. Rob, *Cyperus cyperoides* (L.) Kuntze and *Lagestroemia macrocarpa* Wall ex Kurz) of the total importance value index, and in unburnt area the top five species comprise of 52.7% of the total IVI percentage (*Polyalthia debilis* Finet & Gagnep,. *Heteropogon triticeus* (R.Br.) Stapf ex Craib, *Panicum maximum* Jacq., *Spilanthes iabadicensis* A.H. Moore, *Vetiveria nemoralis* A. Camus of the total importance value index. This shows that for ground flora; the species in unburnt area were more dominant than the species in burnt area. The importance value index for the top five seedlings in burnt area comprise of 73.1% of the total IVI percentage (*Shorea obtusa* Wall.ex Blume., *Polyalthia debilis* (Pierre) Finet & Gagnep, *Xylia xylocarpa* (Roxb.) Taub., *Dillenia obovata* (Blume) Hoogland and *Pterocarpus macrocarpus* Kurz.) of the total importance values and for those found in the unburnt area, it is 81.5% of the total IVI percentage (*Terminalia mucronata* Craib & Hutch, *Dillenia obovata* (Blume) Hoogland, *Casearia grewifolia* Vent., *Gardenia obtusifolia* Roxb. ex Hook.f. and *Beilschmiedia fagifolia* Nees) of the total value index values as shown in figure 1. For saplings, the first five listed species in a burnt area as shown in table 6 consist 81% of the total IVI percentage (*Xylia xylocarpa* (Roxb.) Taub., *Shorea obtusa* Wall.ex Blume., *Sindora siamensis* Teijsm. ex Miq., *Terminalia alata* Heyne.ex Roth and *Diaspyros ehretioides* Wall.) of the total values, and 100% of the total IVI percentage (*Terminalia mucronata* Craib & Hutch, *Dillenia obovata* (Blume) Hoogland, *Casearia grewifolia* Vent., *Gardenia obtusifolia* Roxb. ex Hook.f. and *Beilschmiedia fagifolia* Nees) for the species found in an unburnt area. This shows that the ground flora, seedlings, and saplings the vegetation value was higher in the unburnt areas. This is in agreement with the report of Saravanan *et al* (2014), that an area with higher nitrogen content will have a higher vegetational value. In this study, the unburnt area had higher total nitrogen content. Nitrogen is the nutrient which regulates net plant primary production in most ecosystems, including the deciduous dipterocarp forest (Jones *et al*., 2004). This could have led to the higher biomass of plants in the unburnt area.

For the ground flora; in burnt area, the family Gramineae had the highest importance value index (75.7) and also had the highest number of species (8 species). In unburnt area, the family Gramineae also had the highest importance value index (64.1) and the highest number of species (6 species). This shows that the Gramineae family is the most dominant family of ground flora in burnt and unburnt areas. For the seedlings; in burnt area, the family Dipterocarpaceae had the highest importance value index (106.2), the family Leguminosae and Combretaceae had the highest number of species (2 species). In unburnt area, the family Annonaceae had the highest importance value (120.3) and the family Eurphorbiaceae had the highest number of species. For saplings; in burnt area, the family Leguminosae had the highest importance value index (106.7), the family Leguminosae, Dipterocarpaceae and Combretaceae had the highest number of species (2 species). In unburnt area, the family Combretaceae had the highest importance value index (82.3) and all five families had a single species. Barker *et al.*, 2008 mentioned that the ground flora of the deciduous dipterocarp forest is dominated by the grasses which are from the Gramineae family, and that observation was confirmed in this study since the Gramineae family was the most dominant in the ground flora of both burnt and unburnt areas. According to Vaidhayakarn and Maxwell (2010), dominance by the Gramineae family indicates that the site was exposed to fire; this shows that in this study the burnt area was more exposed to fire than the unburnt area hence the higher dominance by the Gramineae family in the burnt area. The importance value index was higher for the Gramineae family in the burnt area compared to the unburnt area.

Forest profile diagrams make a clear illustration of the forest structure. The canopy profile and layers can indicate the history of an area related to disturbances such as fire. In this study, the burnt area had fewer trees and was less dense than the unburnt area, whereas the mean tree height was high in the burnt area (11.5 m) than in the unburnt area (8.9 m). This shows that frequent fires increase the mean height of the dominant plants. This is contrary to the observation of Bond and Keeley (2005), they mentioned that frequent fires reduce the height of the dominant plants. Yeager *et al*., (2003), observed that in the lowland dipterocarp forest, the canopy cover was less in burnt than in unburnt areas, in this study the canopy percent cover in the burnt area was 19.4%, the unburnt area it was 22.5%.

Yeager *et al.*, (2003) observed that the tree density was lower in burnt area than unburnt area; in a burnt forest in Kutai, there were 70.2 % fewer stems/ha than in an unburnt area. In this study it was observed that the burnt area had 41 trees which is 69 % fewer stems/ha than unburnt area which had 131 trees. Yeager et al., (2003) reported that the average DBH of trees in burnt area was higher than in unburnt area. Similar observations were made in this study; in burnt area the average DBH for trees was 15.4 cm and 9.13 cm in unburnt area.

1.2 Effects of fire on species diversity and evenness

The Shannon-Weiner Index showed that for the ground flora, the unburnt area had higher species diversity than that of the burnt area; the difference was not significant, whereas for the seedlings and saplings, the burnt area had significantly higher species diversity than the unburnt area. According to Sagar et al (2008), such a trend could be caused by having several species as only ground flora or seedlings or saplings in a particular locality (burnt or unburnt area). The species evenness for ground flora in an unburnt area was higher than in a burnt area. For seedlings and saplings, the species evenness was equal in both burnt and unburnt areas. According to Gregory (2006), communities with higher species evenness are the most diverse. It shows that the species are well distributed over the area. In this study it was observed that for the ground flora, the species diversity was higher in the unburnt area than in the burnt area and the same trend was observed for the species evenness. These findings support the observations made by Gregory (2006).

The low ground flora species diversity in the burnt area could be due to the elimination of disturbance sensitive species. According to Peterson and Reich (2008), the elimination of disturbance sensitive species leads to a decrease in plant diversity. The higher species diversity of seedlings and saplings in a burnt area could be due to the high light and space accessibility by the plants in the burnt area. Safford and Harrison (2004) mention that disturbance such as fire makes space and light available thus intensifying competition and productivity amongst plant species which may enhance diversity. The high species diversity of seedlings and saplings in burnt area could also be a result of the high herbivores abundance in burnt area. The herbivores could be contributing to seed distribution from other forest types.

In this study it was observed that there was a relationship between species richness and species diversity for the seedlings and saplings when using the Menhinick's index for species richness and the Shannon index for diversity. When the species richness was higher, the species diversity was higher in that particular site. Prasad and Al-Sagher (2012) used the same indices and also observed the same trend. In their study, in Saklesphura, the species richness was 8.09 and species diversity was 3.33, in Makuta, the species richness was 7.62 and the species diversity was 3.13, in Mudigere, the species richness was 7.49 and the species diversity was 3.05.

1.3 Effects of fire on species similarity

When using the Sorenson's index of similarity, it was found that the similarity between ground flora in a burnt and an unburnt area was 0.38, which means that 38% of the ground flora species occur in both burnt and unburnt areas. The species similarity between saplings found in a burnt area and unburnt area was 0.29, which means that 29% of the seedlings are found in both burnt and unburnt areas. The species similarity of saplings between burnt and unburnt area was 0.15, which means that 15% of the sapling species occur in both and unburnt areas in the deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sanctuary. The species similarity was very low in all the vegetation classes when calculated using the Sorensen's similarity index. The values are closer to zero. When the values are closer to zero than they are to one, the similarity is said to be low (Sorensen, 1948).

2. Effect of Fire on Soil Properties

According to the study of Wantongchai (2008), nutrients can decrease or increase in response to fire, depending on the nature of each element. In this study, the same observation was made. Some nutrients had high quantities in a burnt area and low quantities in an unburnt area and vice versa. Elements such as organic matter, exchangeable potassium, ash, moisture and exchangeable calcium were high in a burnt area than in an unburnt area, and elements such as soil nitrogen, available phosphorus were higher in unburnt area than in burnt area. It is said that physical and chemical properties of soil after fire disturbance change. According to Shaoqing *et al*., (2010), fire results in change in ash composition, change in nitrogen. In this study, changes in ash and nitrogen content were observed. There was a higher ash content in burnt area, which shows that fire results in high ash content and the nitrogen content was low in the burnt areas, which shows that fire affects the soil total nitrogen content in a negative way.

Fire can result in the loss of nutrients such as phosphorus through volatization. Fire can also result in the short term increase of calcium and potassium (Johnson *et al*., 1998). In this study we made the same findings as Johnson *et al*., 1998; there was a very low content of available phosphorus in the burnt areas compared to the unburnt areas. This shows that fire results in the loss of phosphorus. The exchangeable calcium and exchangeable potassium were high in the burnt areas.

In the deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sanctuary, soil textures are sandy loam at the surface and sand clay-loam in the subsurface horizons (Source: Bunyavejchewin *et al.,* 2009). As fire frequency increases, the large soil particles are partly or completely consumed (Bird *et al.,* 2000). According to the USDA (2005), the components of soil texture (sand, silt and clay) have high temperature thresholds are not usually affected by fire unless they are subjected to high temperatures at the mineral soil surface. Wantongchai *et al.*, 2008 state that the sandy loam surface soils also act as fire insulators. The soil properties near or on the soil surface are the most directly exposed to heat that is radiated downward during a fire (USDA, 2005).

3. Effects of Fire on Wildlife Abundance

For the wildlife abundance, the study focused on the trend of herbivores burnt and unburnt areas. The wildlife species of interest were the Asian elephant, gaur, banteng, Sambar deer and common barking deer. The dung density for the elephants, gaur and banteng were used to compare their level of abundance between a burnt area and an unburnt area. The pellet group density of the Sambar deer and common barking deer were used to compare their level of abundance between burnt area and unburnt area.

3.1 Asian elephant (*Elephas maximus* Linnaeus)

In this study it was found that in burnt area, the Asian elephants were more abundant than in unburnt area. The dung density for Asian elephants in a burnt area was significantly higher that than in an unburnt area; 60 dung/ha in e burnt area and 30 dung/ha in unburnt area. The burnt area where the elephants had a higher density is dominated by the Gramineae family, which consists of grasses and is not very far from human settles. Asian elephants prefer feeding on grass; they switch to browse when grasses are unavailable (Sukumar, 2003). According to Fernando and Leimgruber (2011), the highest Asian population densities occur along forest-grasslands or forest-agriculture ecotones where food plants become more abundant and accessible; this is consistent with the findings of the current study. Asian elephants are well adapted to open canopy forests mainly due to their feeding habits of switching between grazing and browsing. Asian elephant densities tend to be higher in disturbed and early-successional dry forests than in mature forests due to the increase in ‘edge’ habitat (Fernando and Leimgruber, 2011). The forest profile diagrams of the study site indicate that the burnt area’s canopy is more open than the unburnt area. This also explains the high abundance of elephants in the area due to their preference of more open canopy forests to facilitate their easy movements in search for suitable food.

3.2 Banteng (*Bos javanicus* D'Alton)

The dung density for banteng was significantly higher in a burnt area (80 dung/ha) than in an unburnt area (60 dung/ha). This indicates that banteng were more abundant in the burnt area than in the unburnt area. The burnt area was more open than the unburnt area as it can be seen in the forest profile diagrams of the two sites, this is one of the reasons the banteng were significantly more abundant in the burnt area than in the unburnt area. The findings of this study are supported by Lakagul and McNeely (1988) who mentioned that banteng prefer more open areas, especially the plains or the deciduous forest. According to Bhumpakphan and McShea (2011), banteng prefer grasses and forbs which are abundant in the open canopy forests of the DDF. The burnt area of the study site meets all the criteria mentioned by the authors; abundant grasses and forbs, open canopy. This results in high preference of the burnt area by the banteng. *Shorea obtusa*, *Heteropogon triticeus, Imperata cylindrica* are amongst the major seasonal forage species eaten by banteng during the dry season (Bhumpakphan and McShea, 2011). In this study these plant species were found in a burnt area during the dry where the banteng density was higher compared to the unburnt area.

3.3 Gaur (*Bos gaurus* Smith)

In both burnt and unburnt areas, there was no dung of gaur found during the time of the study. This could be attributed to the position of the study area which was 500 m either side away from the road towards the HKKWS headquarters. Tapule (2005) observed that there was very low density of Gaur in the study area compared to Sambar deer and banteng due to the vicinity of the road towards the headquarters of HKKWS. The findings were similar to our findings whereby there was no Gaur dung found whereas there were pellets and dung of the Sambar deer and banteng respectively. Bhumpakphan and McShea (2011) mentioned that in Huai Kha Khaeng Wildlife Sanctuary, Gaur use the DDF less during the dry season, except immediately following fires when there is a flush of new grass, this supported the findings made in this study which indicated the absence of Gaur since the study was conducted during the dry season.

3.4 Sambar deer (*Cervus unicolor* Kerr)

The pellet group density for the Sambar deer was significantly higher in burnt area (3250 pellet groups/ha) than in unburnt area (500 pellet groups), this indicates that the Sambar deer abundance was significantly higher in a burnt area than in an unburnt area. In protected forest areas of Thailand, the Sambar deer populations are often concentrated around anthropogenic grass and scrub, rather than the forest itself (Black and Gozalez, 2008). HKKWS is a protected area; the burnt area of the DDF consists of more grass species than unburnt area, which makes it more preferable to the Sambar deer hence the higher abundance of the Sambar deer in burnt area than in unburnt area.

3.5 Common barking deer (*Muntiacus muntjak* Zimmermann)

The pellet group density for the common barking deer in burnt area (750 pellet groups/ha) was significantly higher than in an unburnt area (250 pellet groups/ha). The burnt area had more species of grasses compared to unburnt area. According to Sukmasuang (2001), the common barking deer feeds on various grasses, buds, flowers and fruits. This could be one of the reasons there is a high pellet density in the burnt area. Sukmasuang (2001), states that the suitable habitats for the common barking deer comprise of forest gaps in the deciduous dipterocarp forest. In this study it was observed that from the forest profile, the burnt area has more open gaps that unburnt area, this could be contributing factor to the high pellet density of the common barking deer in the burnt area compared to the unburnt area.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The thesis focused on the species composition of understory vegetation and wildlife abundance in burnt and unburnt areas with the main aim of determining how fire affects the species composition of the DDF which is a fire dependant ecosystem.

1. Fire has a positive effect on the species composition of the understory vegetation (ground flora, seedlings and saplings) in the DDF at HKKWS. There were more species of ground flora, seedlings and saplings in the burnt area compared to the unburnt area. The Menhinick’s index showed that the species richness for the ground flora, seedlings and saplings was higher in the burnt area compared to the unburnt area.

2. The dominant ground flora based on IVI values in burnt area was *Heteropogon triticeus* (30.1) in unburnt area *Polyalthia debilis* (38.4). The dominant seedlings in burnt area were *Shorea obtusa* (106.2) and *Polyalthia debilis* (120.3) in unburnt area. The dominant saplings in burnt area were *Xylia xylocarpa* (63.8) and *Terminalia mucronata* (82.3) in unburnt area.

3. Species diversity of seedlings was 2.39 in burnt area and 2.10 in unburnt area; for saplings it was 2.02 in burnt area and 1.56 in unburnt area. Species diversity of seedlings and saplings was significantly higher in burnt area. This could be attributed to the Dipterocarpaceae family being dominant; it is a fire tolerant family.

4. The species similarity between burnt and unburnt areas was low for ground flora (38%), seedlings (29%) and saplings (15%). This shows that there were many species found exclusively in one site, either burnt or unburnt. For ground flora, there was a total of 55 species found collectively in burnt and unburnt areas, but only 13 species occurred in both bunt and unburnt area. For seedlings, there was a total of 18 species found collectively in burnt and unburnt areas, but only 3 species occurred in both bunt and unburnt areas. For saplings, there was a total of 12 species found collectively in burnt and unburnt areas, but only 1 species occurred in both bunt and unburnt areas.

5. The Gramineae family was the most dominant for the ground flora in both burnt and unburnt areas. For seedlings; the Dipterocarpaceae was the most dominant in burnt area and the Annonaceae family in unburnt area. For saplings; the Leguminosae family was the most dominant in burnt area, and the Combretaceae family was the most dominant in unburnt area.

6. For ground flora; in both burnt and unburnt areas, the Gramineae family was the most dominant. *Imperata cylindrica* (L.) P.Beauv., was only found in burnt area. *Chromolaena odorata* (L.) King & H. Rob which is an invasive species in Thailand was amongst the five most important species found in a burnt area in the Deciduous Dipterocarp Forest.

7. There were trees speicies in unburnt area than in burnt area. This resulted in higher percent cover in unburnt area than in burnt area. Fire results in thinning of the tree species. The average tree height was higher in the burnt area than in the unburnt area.

8. There was higher large herbivore abundance in burnt area than in unburnt area. The dung and pellet density showed that Asian elephants, banteng, Sambar deer and barking deer were more abundant in burnt area than in unburnt area. There was no indication of the presence of gaur in both burnt and unburnt areas, this could be attributed to the DDF not being a suitable habitat for gaur; they prefer the moist forest types. Gaur did not inhabit the study site.

Recommendations

Based on the study

1. To maintain the high species diversity of the fire-dependant species, fire should be used as a management tool in the deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sanctuary. This will promote the species abundance and biodiversity in the forest of the fire dependant species.

2. The wildlife needs such as food and cover have to be taken into consideration during the fire season, thus controlled rotation burning has to be practiced to ensure that a certain portion of the DDF is conserved for all year-round utilization by the wildlife.

3. The findings of the study can be used to determine the carrying capacity of large herbivores based on available forage.

Future research and management

1. It is recommended that similar studies be carried out during all the different seasons in Thailand in order to determine the species composition and wildlife abundance during the different seasons of the year.

2. Records of fire occurrences and mapping should be kept to ensure the possibility and success of long-term studies and provide an insight on the fire regimes and trend in the DDF.

3. The understory vegetation has not been studied in detail, yet it is provides most of the herbivores needs such as food and cover. It is recommended that more studies on the understory vegetation should be conducted; this will also help in determining any changes in the structure of the forest and early identification of invasive species or rare species.

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APPENDIX

Appendix Table 1 Species composition of ground flora seedlings and saplings found in burnt and unburnt areas.

No.	Family	Botanical Name	B	UB
1	Anacardiaceae	*Lannea coromandelica* (Houtt.) Merr.	x	–
2	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	–	x
3	Annonaceae	*Uvaria argentea* Blume	x	–
4	Apocynaceae	*Holarrhena curtisii* King & Gamble	x	–
5	Barringtoniceae	*Careya sphaerica* Roxb.	–	x
6	Bignoniaceae	*Fernandoa adenophylla* (Wall. ex G.Don) Steenis	x	–
7	Bignoniaceae	*Markhamia stipulata* Seem.	–	x
8	Combretaceae	*Terminalia alata* Heyne.ex Roth	x	–
9	Combretaceae	*Terminalia chebula* Retz	x	–
10	Combretaceae	*Terminalia mucronata* Craib & Hutch.	x	–
11	Commelinaceae	*Commelina diffusa* Burm.f	x	x
12	Commelinaceae	*Murdannia spirata* (L.) G. Bruckn.	–	x
13	Compositae	*Elephantopas scaber* L.	–	x
14	Compositae	*Chromolaena odorata* (L.) R.M. King & H. Rob.	x	x
15	Compositae	*Praxelis clematidea* R.M. King& H. Rob.	x	x
16	Compositae	*Spilanthes iabadicensis* A.H. Moore	–	x
17	Costaceae	*Costus speciosus* (Koen ex. Retz.) Sm.	x	–
18	Cyperaceae	*Cyperus cyperoides* (L.) Kuntze	x	x
19	Cyperaceae	*Cyperus haspan* L.	–	x
20	Cyperaceae	*Diplacrum caricinum* R. Br.	x	x
21	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	–	x
22	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	x	–
23	Dipterocarpaceae	*Shorea siamensis* Miq.	x	–
24	Ebenaceae	*Diaspyros enretiodes* Wall. ex G.Don	x	–
25	Erythroxylaceae	*Erythroxylum cambodianum* Pierre	–	x
26	Euphorbiaceae	*Aporosa villosa* (Wall. ex Lindl.) Baill.	x	x
27	Euphorbiaceae	*Croton hutchinsonianus* Hosseus	x	x
28	Flacourtiaceae	*Casearia grewifolia* Vent.	–	x
29	Gramineae	*Cyrtococcum patens* (L.) A. Camus	x	x
30	Gramineae	*Eragrostis atrovirens* (Desf.) Steud.	–	x
31	Gramineae	*Heteropogon triticeus* (R.Br.) Stapf ex Craib	x	x
32	Gramineae	*Imperata cylindrica* (L.) P. Beauv.	x	–
33	Gramineae	*Oplismenus compositus* (L.) P. Beauv.	–	x

Appendix Table 1 (Continued)

No.	Family	Botanical Name	B	UB
34	Gramineae	*Panicum maximum* Jacq.	–	x
35	Gramineae	*Pennisetum polystachion* L. Schult.	x	–
36	Gramineae	*Sacciolepis turgida* Ridl.	x	–
37	Gramineae	*Setaria parviflora* (Poir.) Kerguelen	x	–
38	Gramineae	*Themeda triandra* Forssk.	x	–
39	Gramineae	*Vetiveria nemoralis* A. Camus	x	x
40	Guttiferae	*Cratoxylum formosum* (Jack) Dyer.	x	–
41	Labiatae	*Vitex limonifolia* Wall.	–	x
42	Labiatae	*Vitex penuncularis* Wall ex Schauer	x	x
43	Labiatae	*Pogostemon quadrifolius* Kuntze.	x	–
44	Lauraceae	*Beilschmiedia fagifolia* Nees	–	x
45	Lauraceae	*Litsea glutinosa* (Lour.) C.B. Rob.	–	x
46	Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.	–	x
47	Leguminosae	Unknown sp 2	–	x
48	Leguminosae-Caesalpinioideae	*Bauhinia saccocalx* Pierre.	–	x
49	Leguminosae-Caesalpinioideae	*Sindora siamensis* Teijsm.& Miq.	x	–
50	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	x	–
51	Leguminosae-Papilionoideae	*Dalbergia cultrata* Graham ex Benth.	x	–
55	Malvaceae	*Colona auriculata* (Desv.) Craib	–	x
56	Malvaceae	*Sida cordifolia* L.	x	–
57	Melastomataceae	*Osbeckia chinensis* L	x	x
58	Myrtaceae	*Syzygium cumini* (L.) Skeels	x	–
59	Oleaceae	*Jasminum grandiflorum* (L.) Kobuski	x	x
60	Ranunculaceae	*Clematis meyeniana* Walp.	–	x
61	Rubiaceae	*Catunaregam tomentosa* (Blume ex DC) Tirveng	–	x
62	Rubiaceae	*Gardenia obtusifolia* Roxb. ex Kurz	–	x
63	Rubiaceae	*Metadina trichotoma* (Zoll. Ex Merr.) Bakh.f.	x	–
64	Rubiaceae	*Paederia linearis* Hook. F.	x	–
65	Rubiaceae	*Spermacoce pusilla* Wall.	x	x
66	Scrophulariceae	Unknown sp1	x	–
67	Stereuliaceae	*Helicteres angustifolia* L.	–	x

Appendix Table 1 (Continued)

No.	Family	Botanical Name	B	UB
68	Tiliaceae	*Grewia eriocarpa* Juss.	x	−
69	Tiliaceae	*Grewia hirsuta* Vahl.	−	x
70	Zingiberaceae	*Curcuma plicata* Wall.	x	−

Appendix Table 2 IVI of gound flora found in a burnt area.

No.	Botanical name	Occurrence	RF (%)	RDo (%)	IVI
1	*Heteropogon triticeus* (R.Br.) Stapf ex Craib	14	19.4	10.7	30.1
2	*Vetiveria nemoralis* A. Camus	3	4.2	17.7	21.9
3	*Chromolaena odorata* (L.) R.M. King & H. Rob.	7	9.7	9.3	19
4	*Cyperus cyperoides* (L.) O. Kuntze	4	5.6	4.9	10.4
5	*Lagestroemia macrocarpa* Wall.	3	4.2	5.9	10.1
6	*Holarrhena curtisii* King & Gamble	1	1.4	6.8	8.2
7	*Vigna sp*	4	5.6	2.3	7.8
8	*Sida cordifolia* L.	1	1.4	6.3	7.7
9	*Themeda triandra* Forssk. G	2	2.8	4.8	7.6
10	*Osbeckia chinensis* L	4	5.6	1.5	7
11	*Jasminum grandiflorum* (L.) Kobuski	1	1.4	4.3	5.7
12	*Pterocarpus macrocarpus* Kurz.	1	1.4	4	5.4
13	*Sacciolepis turgida* Ridl.	1	1.4	3.8	5.2
14	*Pogostemon quadrifolius* Kuntze.	3	4.2	0.5	4.6
15	*Imperata cylindrica* (L.) P.Beauv.	1	1.4	2.5	3.9
16	*Syzygium cumini* (L.) Skeels	1	1.4	2.3	3.7
17	Unknown sp1	2	2.8	0.8	3.6
18	*Uvaria argentea* Blume	2	2.8	0.8	3.6
19	*Shorea obtusa* Wall.	1	1.4	2	3.4
20	*Pennisetum polystachion* L. Schult.	1	1.4	1.8	3.2
21	*Costus speciosus* (Koen ex. Retz.) Sm.	1	1.4	1.5	2.9
22	*Setaria parviflora* (Poir.) Kerguelen	1	1.4	1	2.4

Appendix Table 2 (Continued)

No.	Botanical name	Occurrence	RF (%)	RDo (%)	IVI
23	*Curcuma plicata* Wall.	1	1.4	1	2.4
24	*Xylia xylocarpa* (Roxb.) Taub.	1	1.4	0.8	2.1
25	*Terminalia mucronata* Craib & Hutch.	1	1.4	0.5	1.9
26	*Praxelis clematidea* R.M. King& H. Rob.	1	1.4	0.5	1.9
27	*Croton hutchinsonianus* Hosseus	1	1.4	0.5	1.9
28	*Metadina trichotoma* (Zoll. Ex Merr.) Bakh.f.	1	1.4	0.3	1.7
29	*Diplacrum caricinum* R. Br.	1	1.4	0.3	1.6
30	*Dalbergia cultrata* Graham ex Benth.	1	1.4	0.2	1.5
31	*Commelina diffusa* Burm.f.	1	1.4	0.1	1.5
32	*Paederia linearis* Hook. f.	1	1.4	0.1	1.5
33	*Fernandoa adenophylla* (Wall. ex G.Don) Steenis	1	1.4	0.1	1.5
34	*Cyrtococcum patens* (L.) A. Camus	1	1.4	0.1	1.5
35	*Spermacoce pusilla* Wall.	1	1.4	0	1.4

Appendix Table 3 IVI of ground flora found in an unburnt area

No.	Botanical name	Occurrence	RF (%)	RDo (%)	IVI
1	*Polyalthia debilis* (Pierre) Finet & Gagnep.	4	4.8	33.6	38.4
2	*Heteropogon triticeus* (R.Br.) Stapf ex Craib	13	15.7	6.3	21.9
3	*Panicum maximum* Jacq.	4	4.8	11.1	15.9
4	*Spilanthes iabadicensis* A.H. Moore	6	7.2	7.4	14.6
5	*Vetiveria nemoralis* A. Camus	6	7.2	7.2	14.4
6	*Chromolaena odorata* (L.) R.M. King & H. Rob.	4	4.8	7.3	12.1
7	*Casearia grewifolia* Vent.	1	1.2	8.6	9.8
8	*Cyrtococcum patens* (L.) A. Camus	4	4.8	1.7	6.6

Appendix Table 3 (Continued)

No.	Botanical name	Occurrence	RF (%)	RDo (%)	IVI
9	*Praxelis clematidea* R.M. King& H. Rob.	4	4.8	1.7	6.5
10	*Cyperus cyperoides* (L.) Kuntze	3	3.6	2.1	5.7
11	*Elephantopus scaber* L.	3	3.6	1.6	5.2
12	*Commelina diffusa* Burm.f	3	3.6	0.9	4.5
13	*Barringtonia acutangula* (L.) Gaertn.	1	1.2	2.9	4.2
14	*Eragrostis atrovirens* (Desf.) Steud.	2	2.4	1.6	4
15	*Cyperus haspan* L.	3	3.6	0.3	3.9
16	*Xylia xylocarpa* (Roxb.) Taub.	2	2.4	1.1	3.5
17	Unknown sp 2	2	2.4	0.8	3.3
18	*Erythroxylum cambodianum* Pierre	2	2.4	0.1	2.5
19	*Spermacoce pusilla* Wall.	2	2.4	0.1	2.5
20	*Croton hutchinsonianus* Hosseus	1	1.2	1.2	2.4
21	*Careya sphaerica* Roxb.	1	1.2	0.5	1.7
22	*Litsea glutinosa* (Lour.) C.B.Rob.	1	1.2	0.5	1.7
23	*Helicteres angustifolia* L.	1	1.2	0.4	1.6
24	*Jasminum grandiflorum* (L.) Kobuski	1	1.2	0.3	1.5
25	*Clematis meyeniana* Walp.	1	1.2	0.3	1.5
26	*Murdannia spirata* (L.) G. Bruckn.	1	1.2	0.3	1.5
27	*Beilschmiedia fagifolia* Nees	1	1.2	0.1	1.3
28	*Oplismenus compositus* (L.) P.Beauv.	1	1.2	0	1.2
30	*Colona auriculata* (Desv.) Craib	1	1.2	0	1.2
31	*Osbeckia chinensis* L.	1	1.2	0	1.2
32	*Diplacrum caricinum* R. Br.	1	1.2	0	1.2
33	*Markhamia stipulata* Seem.	1	1.2	0	1.2

Appendix Table 4 IVI of seedlings found in a burnt area

No.	Botanical name	Quantity	RF (%)	RD (%)	Rdo (%)	IVI
1	*Shorea obtusa* Wall.ex Blume	27	18.5	41.5	46.2	106.2
2	*Polyalthia debilis* (Pierre) Finet & Gagnep.	14	6.3	21.5	12.4	40.2
3	*Xylia xylocarpa* (Roxb.) Taub.	4	12.5	6.2	7.8	26.5
4	*Dillenia obovata* (Blume) Hoogland	5	6.3	7.7	10.2	24.2
5	*Pterocarpus macrocarpus* Kurz.	4	12.5	6.2	3.4	22.1
6	*Lannea coromandelica* (Houtt.) Merr.	2	6.3	3.1	10.7	20.1
7	*Grewia eriocarpa* Juss.	4	6.3	6.2	3.9	16.4
8	*Terminalia alata* Heyne.ex Roth	1	6.3	1.5	1.8	9.6
9	*Cratoxylum formosum* (Jack) Dyer.	1	6.3	1.5	1.8	9.6
10	*Fernandoa adenophylla* (Wall. ex G.Don) Steenis	1	6.3	1.5	1.2	9
11	*Vitex penuncularis* Wall ex Schauer	1	6.3	1.5	0.6	8.4
12	*Terminalia chebula* Retz	1	6.3	1.5	0	7.8

Appendix Table 5 IVI of seedlings found in an unburnt area

No.	Botanical name	Quantity	RF (%)	RD (%)	Rdo (%)	IVI
1	*Polyalthia debilis* (Pierre) Finet & Gagnep.	30	27.3	45	48	120.3
2	*Terminalia mucronata* Craib & Hutch.	19	9.1	28.8	15.3	53.2
3	*Croton hutchinsonianus* Hosseus	7	9.1	10.6	7	26.7
4	*Dillenia obovata* (Blume) Hoogland	4	9.1	6.1	10	25.2
5	*Aporosa villosa* (Wall. ex Lindl.) Baill.	1	9.1	1.5	8.5	19.1
6	*Xylia xylocarpa* (Roxb.) Taub.	1	9.1	1.5	5.5	16.1
7	*Grewia hirsuta* Vahl	1	9.1	1.5	3.1	13.7
8	*Vitex limonifolia* Wall.	2	9.1	3	1.1	13.2
9	*Bauhinia saccocalyx* Pierre	1	9.1	1.5	1.4	12

Appendix Table 6 IVI of saplings found in a burnt area

No.	Botanical name	Quantity	RF (%)	RD (%)	Rdo (%)	IVI
1	*Xylia xylocarpa* (Roxb.) Taub.	3	18.2	27.3	18.4	63.8
2	*Shorea obtusa* Wall.ex Blume	2	18.2	18.2	24.5	60.9
3	*Sindora siamensis* Teijsm.& Miq.	1	9.1	9.1	24.7	42.9
4	*Terminalia alata* Heyne.ex Roth	1	18.2	9.1	12.3	39.6
5	*Diaspyros enretioides* Wall. ex G.Don	1	9.1	9.1	17.6	35.7
6	*Terminalia mucronata* Craib & Hutch.	1	9.1	9.1	1	19.2
7	*Shorea siamensis* Miq.	1	9.1	9.1	0.9	19.1
8	*Metadina trichotoma* (Zoll. Ex Merr.) Bakh.f.	1	9.1	9.1	0.4	18.6

Appendix Table 7 IVI of saplings found in an unburnt area

No.	Botanical name	Quantity	RF (%)	RD (%)	Rdo (%)	IV (%)
1	*Terminalia mucronata* Craib & Hutch.	2	16.7	28.4	37.2	82.3
2	*Dillenia obovata* (Blume) Hoogland	1	33.3	14.2	26.4	73.9
3	*Casearia grewifolia* Vent.	2	16.7	28.4	7.4	52.5
4	*Gardenia obtusifolia* Roxb. ex Kurz	1	16.7	14.2	17.7	48.6
5	*Beilschmiedia fagifolia* Nees	1	16.7	14.2	11.3	42.2

Appendix Table 8 Forest profile data for burnt area

No.	Family	Botanical Name	Distance (m)		DBH (cm)	Max. height(m)
			X	Y		
1	Anacardiaceae	*Buchanania lanzan* Spreng.	9	3	10.1	11
2	Anacardiaceae	*Buchanania lanzan* Spreng.	26.2	1	4.7	3
3	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	30.3	5	10.1	8
4	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	33.5	5	11.7	9
5	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	35.1	6	7.5	7
6	Bignoniaceae	*Heterophragma sulfureum* Kurz.	32	6.5	9.7	9
7	Combretaceae	*Terminalia alata* Heyne.ex Roth	29.9	7.8	4.6	4
8	Combretaceae	*Terminalia chebula* Retz	25.8	2.5	4.5	5
9	Combretaceae	*Terminalia mucronata* Craib & Hutch.	8.5	2.8	35	20
10	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	15.9	0.6	33.5	16
11	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	20.1	3.5	15.1	10
12	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	22.5	9	15.1	15
13	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	27	9	7.2	7
14	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	37	6	13.5	10
15	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	39.8	2	18.2	15
16	Dipterocarpaceae	*Shorea siamensis* Miq.	20.3	5	35	18
17	Dipterocarpaceae	*Shorea siamensis* Miq.	30.2	1.5	23.5	18
18	Dipterocarpaceae	*Shorea siamensis* Miq.	38.8	1.2	12	7

Appendix Table 8 (Continued)

No.	Family	Botanical Name	Distance (m)		DBH (cm)	Max. height(m)
			X	Y		
19	Dipterocarpaceae	*Shorea siamensis* Miq.	38.8	3	23.9	18
20	Dipterocarpaceae	*Shorea siamensis* Miq.	43	7.5	19.2	15
21	Dipterocarpaceae	*Shorea siamensis* Miq.	2.9	1	11.5	7
22	Dipterocarpaceae	*Shorea siamensis* Miq.	10.8	10	21.3	18
23	Leguminosae- Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	43	7.2	11.6	10
24	Leguminosae- Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	45.7	1	15.6	15
25	Leguminosae- Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	46	3	20.2	17
26	Leguminosae- Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	1.8	8.1	14.6	15
27	Leguminosae- Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	6.1	1.8	28.5	18
28	Leguminosae- Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	8	1	17.8	15
29	Leguminosae- Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	19.9	5	12.2	9
30	Leguminosae- Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	30.5	7	24.6	19
31	Leguminosae- Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	39	6	18.3	12
32	Leguminosae-Papilionoideae	*Pterocarpus macrocarpus* Kurz.	23	8.5	10.8	10
33	Loganiaceae	*Strychnos nux-vomica* L.	1.1	1.8	25.5	15
34	Ochnaceae	*Ochna intergerrima (*Lour.) Merr.	10.9	9.7	14.2	10
35	Ochnaceae	*Ochna intergerrima (*Lour.) Merr.	17.8	8	11.5	10

Appendix Table 8 (Continued)

No.	Family	Botanical Name	Distance (m)		DBH (cm)	Max. height(m)
			X	Y		
36	Ochnaceae	*Ochna intergerrima (*Lour.) Merr.	33	8	12.4	9
37	Ochnaceae	*Ochna intergerrima (*Lour.) Merr.	39.8	8	9.7	9
38	Rubiaceae	*Gardenia obtusifolia* Roxb. ex Kurz	14.1	2	5	4
39	Rubiaceae	*Gardenia obtusifolia* Roxb. ex Kurz	25.6	3	4.7	3.5
40	Rubiaceae	*Mitragyna rotundifolia* (Roxb.) Kuntze	8.8	0	9.5	12
41	Rubiaceae	*Mitragyna rotundifolia* (Roxb.) Kuntze	39.8	6	16.1	10

Appendix Table 9 Forest profile data for unburnt area

No.	Family	Botanical Name	Distance (m)		DBH (cm)	Max. height(m)
			X	Y		
1	Anacardiaceae	*Buchanania lanzan* Spreng	12.4	2	4.8	4
2	Anacardiaceae	*Gluta usitata* (Wall.) Ding Hou	17.5	2.75	16.8	13
3	Anacardiaceae	*Buchanania lanzan* Spreng	28.2	9.9	8.3	9
4	Anacardiaceae	*Buchanania lanzan* Spreng	31.4	9.8	8.7	9
5	Anacardiaceae	*Buchanania lanzan* Spreng	32.8	2.8	14.7	15
6	Anacardiaceae	*Buchanania lanzan* Spreng	39.1	4.8	9.5	12
7	Anacardiaceae	*Buchanania lanzan* Spreng	40.1	1.3	21.6	13.5
8	Anacardiaceae	*Buchanania lanzan* Spreng	48.2	6.7	4.6	7
9	Anacardiaceae	*Gluta usitata* (Wall.) Ding Hou	47	3	22.3	15
10	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	4.9	9.4	6.8	3
11	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	8.3	4.75	9.9	4.7
12	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	9.3	4.8	4.7	5
13	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	10.3	7.1	5.3	4
14	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	12.5	1.9	8	5
15	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	23.05	5.4	5	3
16	Annonaceae	*Polyalthia debilis* (Pierre) Finet & Gagnep.	47	1	6	5
17	Combretaceae	*Terminalia alata* Heyne.ex Roth.	4.7	9.5	7.9	9.5
18	Combretaceae	*Terminalia alata* Heyne.ex Roth.	1.2	2.5	5.9	5

Appendix Table 9 (Continued)

No.	Family	Botanical Name	Distance (m)		DBH (cm)	Max. height(m)
			X	Y		
19	Combretaceae	*Terminalia alata* Heyne.ex Roth.	14.9	0.8	7.1	7.5
20	Combretaceae	*Terminalia alata* Heyne.ex Roth.	17	9.2	6	3.5
21	Combretaceae	*Terminalia alata* Heyne.ex Roth.	6.4	5.95	6.8	5
22	Combretaceae	*Terminalia alata* Heyne.ex Roth.	14.3	4.25	5.1	5.5
23	Combretaceae	*Terminalia alata* Heyne.ex Roth.	19	8.5	7.1	3.5
24	Combretaceae	*Terminalia alata* Heyne.ex Roth.	19.7	3.6	4.8	3
25	Combretaceae	*Terminalia alata* Heyne.ex Roth.	21	5.2	4.6	2.5
26	Combretaceae	*Terminalia alata* Heyne.ex Roth.	23	3.85	5.7	2.5
27	Combretaceae	*Terminalia alata* Heyne.ex Roth.	25.15	3.15	8.1	9.5
28	Combretaceae	*Terminalia alata* Heyne.ex Roth.	34.7	7.8	7.3	9
29	Combretaceae	*Terminalia alata* Heyne.ex Roth.	38	1.4	6.4	9
30	Combretaceae	*Terminalia alata* Heyne.ex Roth.	29.2	8.6	6.6	10
31	Combretaceae	*Terminalia alata* Heyne.ex Roth.	42.2	1.5	6.6	12
32	Combretaceae	*Terminalia mucronata* Craib & Hutch.	9.5	5.6	14.9	14
33	Combretaceae	*Terminalia mucronata* Craib & Hutch.	10.4	4	5	2.5
34	Combretaceae	*Terminalia mucronata* Craib & Hutch.	11.1	8.5	9.1	9
35	Combretaceae	*Terminalia mucronata* Craib & Hutch.	11.8	4.55	7.6	11.5
36	Combretaceae	*Terminalia mucronata* Craib & Hutch.	14.2	5.65	7.9	11.5

Appendix Table 9 (Continued)

No.	Family	Botanical Name	Distance (m)		DBH (cm)	Max. height(m)
			X	Y		
37	Combretaceae	*Terminalia mucronata* Craib & Hutch.	0.9	6.3	9.6	9
38	Combretaceae	*Terminalia mucronata* Craib & Hutch.	5.2	6.1	14.2	14
39	Combretaceae	*Terminalia mucronata* Craib & Hutch.	14.9	4.15	6	9.5
40	Combretaceae	*Terminalia mucronata* Craib & Hutch.	16	9.6	9.7	12.5
41	Combretaceae	*Terminalia mucronata* Craib & Hutch.	18	7.2	6.9	10
42	Combretaceae	*Terminalia mucronata* Craib & Hutch.	20.45	2.4	6.5	8
43	Combretaceae	*Terminalia mucronata* Craib & Hutch.	22.1	6.25	4.8	8
44	Combretaceae	*Terminalia mucronata* Craib & Hutch.	18.3	3.2	5.4	9
45	Combretaceae	*Terminalia mucronata* Craib & Hutch.	24.15	3.4	5.2	8
46	Combretaceae	*Terminalia mucronata* Craib & Hutch.	29.5	7.05	5.8	10
47	Combretaceae	*Terminalia mucronata* Craib & Hutch.	31.4	8.8	6.5	10
48	Combretaceae	*Terminalia mucronata* Craib & Hutch.	39.5	0.2	10.1	13
49	Combretaceae	*Terminalia mucronata* Craib & Hutch.	39.5	0.2	10.1	13
50	Combretaceae	*Terminalia mucronata* Craib & Hutch.	48	1.2	7.7	13
51	Combretaceae	*Terminalia mucronata* Craib & Hutch.	49	6.7	10.5	13
52	Combretaceae	*Terminalia mucronata* Craib & Hutch.	49.6	6.1	10.5	11
53	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	11	0.7	6	4
54	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	11.8	2.3	5.1	3

Appendix Table 9 (Continued)

No.	Family	Botanical Name	Distance (m)		DBH (cm)	Max. height(m)
			X	Y		
55	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	31.3	5.1	6.3	5
56	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	35.1	2.3	8.9	5
57	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	35.7	8.8	5.2	5.5
58	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	38.4	8.65	5.3	8
59	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	40.5	0.2	5	4
60	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	42.2	0.15	4.6	5
61	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	44.2	1	7.7	13
62	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	47.5	0.2	5.1	7
63	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	47.5	0.5	5.1	5
64	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	49.5	4.4	5.9	6
65	Dilleniaceae	*Dillenia obovata* (Blume) Hoogland	49.4	6.6	6.8	8
66	Dipterocarpaceae	*Dipterocarpus obtusifolius* Teijsm.ex Miq.	17.5	0.3	14.2	11
67	Dipterocarpaceae	*Dipterocarpus obtusifolius* Teijsm.ex Miq.	27	5.2	11	8
68	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.	27.35	7.95	12.2	9
69	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.	31	3.8	9.7	11.5
70	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.	34.7	8.8	7.5	3
71	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.	36.7	9.6	20.4	14
72	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.	37	1.4	29.1	20

Appendix Table 9 (Continued)

No.	Family	Botanical Name	Distance (m)		DBH (cm)	Max. height(m)
			X	Y		
72	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.	37	1.4	29.1	20
73	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.	39.8	1.8	25.4	18
74	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.	39.8	1.8	25.4	18
75	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.	41.5	2	24.1	20
76	Dipterocarpaceae	*Dipterocarpus tuberculatus* Roxb.	43.15	2.3	19.4	17
77	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	0.8	6.1	9.4	6.5
78	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	3.7	2.95	15.9	11.5
79	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	19.9	6.7	19.7	14.5
80	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	21	6.2	9.2	11
81	Dipterocarpaceae	*Shorea obtusa* Wall.ex Blume	27.15	6.1	6.2	4.5
82	Dipterocarpaceae	*Shorea siamensis* Miq.	18.3	3.1	6.3	9
83	Dipterocarpaceae	*Shorea siamensis* Miq.	32	4.65	9.9	12.5
84	Dipterocarpaceae	*Shorea siamensis* Miq.	42.1	1.5	17.8	18
85	Ebenaceae	*Diaspyros enretioides* Wall. ex G.Don	13.2	4.2	7	5.5
86	Ebenaceae	*Diaspyros enretioides* Wall. ex G.Don	28	4.75	6.4	5.5
87	Euphorbiaceae	*Antidesma ghaesembilla* Gaertn.	46.1	3	9.3	12
88	Euphorbiaceae	*Antidesma ghaesembilla* Gaertn.	2.9	1.2	5.7	2.5
89	Euphorbiaceae	*Antidesma ghaesembilla* Gaertn.	5	6.6	8.3	9

Appendix Table 9 (Continued)

No.	Family	Botanical Name	Distance (m)		DBH (cm)	Max. height(m)
			X	Y		
90	Euphorbiaceae	*Antidesma ghaesembilla* Gaertn.	9.3	4.45	7.9	6
91	Euphorbiaceae	*Antidesma ghaesembilla* Gaertn.	9.5	4.6	5.5	4.7
92	Euphorbiaceae	*Antidesma ghaesembilla* Gaertn.	30.05	7.55	8.6	9.5
93	Euphorbiaceae	*Antidesma ghaesembilla* Gaertn.	39.5	3.3	7	7
94	Euphorbiaceae	*Antidesma ghaesembilla* Gaertn.	39.5	3.3	7	7
95	Euphorbiaceae	*Aporosa villosa* (Wall. ex Lindl.) Baill.	1	7.5	6.7	9
96	Euphorbiaceae	*Aporosa villosa* (Wall. ex Lindl.) Baill.	1.1	7.9	9.9	9.5
97	Euphorbiaceae	*Phyllanthus emblica* L.	43.15	3	12	13
98	Flacourtiaceae	*Casearia grewifolia* Vent.	49	7.6	6.7	7
99	Labiatae	*Vitex peduncularis* Wall ex. Shauer.	47.1	1	12.6	14
100	Lauraceae	*Beilschmiediia fagifolia* Nees.	17	0.75	4.7	6
101	Lauraceae	*Beilschmiediia fagifolia* Nees.	24	4	7.1	6.5
102	Lauraceae	*Beilschmiediia fagifolia* Nees.	49.9	8.65	6.2	7.5
103	Lauraceae	*Beilschmiediia fagifolia* Nees.	49.8	8.95	5.6	7
104	Lauraceae	*Beilschmiediia fagifolia* Nees.	18	8	6.6	7.5
105	Lecythidaceae	*Careya arborea* Roxb.	23.9	4	10.4	10
106	Leguminosae-Caesalpiniodeae	*Bauhinia saccocalx* Pierre	37	1.6	7.6	6

Appendix Table 9 (Continued)

No.	Family	Botanical Name	Distance (m)		DBH (cm)	Max. height(m)
			X	Y		
107	Leguminosae-Caesalpiniodeae	*Bauhinia saccocalx* Pierre	19.1	1.3	4.9	3
108	Leguminosae-Caesalpiniodeae	*Bauhinia saccocalx* Pierre	1.7	2.4	8.8	9.5
109	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	11	7	7.8	10
110	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	12.3	6.5	11.9	15
111	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	16	0.6	8.2	11.5
112	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	17.05	2.4	6	10.5
113	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	17.05	4.7	7.9	10
116	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	18.5	4.7	8.3	8.5
117	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	49.55	8.15	5.4	7.5
118	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	31.4	5.3	6.8	7

Appendix Table 9 (Continued)

No	Family	Botanical Name	Distance (m)		DBH (cm)	Max. height(m)
			X	Y		
119	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	19.3	1.2	7.2	11.5
120	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	23.7	2.65	9.1	11.5
121	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	23.8	2.65	7.3	10
122	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	29.65	7.4	8	11
123	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	31.3	3.7	16.2	15
124	Leguminosae-Mimosoideae	*Xylia xylocarpa* (Roxb.) Taub.	42.25	1.5	6.3	11
125	Leguminosae-Papilionoideae	*Dalbergia cultrata* Graham ex Benth.	5	8.6	10.8	10
126	Leguminosae-Papilionoideae	*Dalbergia cultrata* Graham ex Benth.	8.4	5.8	6.3	5
127	Leguminosae-Papilionoideae	*Dalbergia cultrata* Graham ex Benth.	9.3	7.5	8.7	5
129	Leguminosae-Papilionoideae	*Dalbergia cultrata* Graham ex Benth.	10.5	6.7	7.5	6

Appendix Table 9 (Continued)

No	Family	Botanical Name	Distance (m)		DBH (cm)	Max. height(m)
			X	Y		
130	Leguminosae-Papilionoideae	*Dalbergia oliveri* Gamble	32	6.15	22.1	15
131	Leguminosae-Papilionoideae	*Dalbergia oliveri* Gamble	48.2	1	12.6	13

Appendix Table 10 Statistical analysis for species diversity

	One-Sample Test					
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Dflora	81.893	79	.000	3.15987	3.0831	3.2367
Dseedlings	36.133	19	.000	2.24500	2.1150	2.3750
Dsaplings	29.665	19	.000	1.79000	1.6637	1.9163

Appendix Table 11 Statistical analysis for wildlife abundance

	One-Sample Test					
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Elephant	4.414	19	.000	4.50000	2.3661	6.6339
Banteng	3.376	19	.003	7.00000	2.6598	11.3402
Sambar	2.500	79	.014	46.87500	9.5554	84.1946
Barking	3.206	79	.002	12.50000	4.7383	20.2617

CURRICULUM VITAE

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